Vol. XLVIII

TABLE OF CONTENTS.

No. 23
(28 pages and inset.)

Page.

ENGINEERING NEWS OF THE WEEK 461

LEADING ARTICLES:

Modern Turbine Practice and the Development of Water Powers (with two-page plate and other illustrations) ..... John Wolf Thurso. 462
Recent Practice in Machine Tools ..... Jas. K. Cullen. 471
The Freezing Process for Building the Hudson River Tunnel of the Pennsylvania R. R. (illustrated) 472
Cost of Copper Mining in the Lake Superior District 473
An Experimental Steel Trackway in New York City (illustrated) 477
Notes from Water-Works Reports 477
Failure of a Concrete Floor at Chicago (illustrated) 478
The New York Rapid Transit Ry., XIV.; Contract Section VII. (illustrated) 478
The New Works for the Biological Treatment of the Sewage of Manchester, England ..... J. P. Wilkinson. 482
Placer Gold Deposits in Alaska 483
Cost of Tunneling and Mining by the "Hole Contract" System 483
Remarks on the New Designs of Naval Vessels ..... Rear Admiral Francis T. Bowles. 483
The Demolition of a 150-ft. Brick Chimney by Dynamite (illustrated) ..... W. J. Douglas. 484
The Development of Modern Ordnance and Armor in the United States (concluded) ..... Rear-Admiral Chas. O'Neil, U. S. N. 485
Wrought-Iron Armature Frames for Large Alternators (illustrated) 488

EDITORIAL COMMENT.—Routes for the New York Barge Canal—Fire-Trap Construction for Sound Steamers—The Chicago Water Supply—The Union of the Manhattan Elevated and Rapid Transit Railway Companies in New York City—Is Granite a Mineral?—A Treatise on Water Power Development—The Need of Engineering Advice in Warehouse Construction.—The Corrosion of Cast-Iron Propeller Blades 474

EDITORIAL.—Heat Resistance, the Reciprocal of Heat Conductivity 475

LETTERS TO THE EDITOR.—What Constitutes an Engine Load? A. C. T.—Office Hours for Draftsmen: "Short Hours."—Some Legends of Blast Furnace Construction: L. F. G.—An Explanation of Unaccounted-for Water: "2 Wall St."—Floorbeam Hangers: The Relative Safety of Buildings: C. A. P. Turner.—Notes and Queries 476

TWO NEW FALL RIVER LINE STEAMERS are to be built by the Fore River Ship & Engine Co., one for passenger service and one for freight service. The passenger steamer will be similar in her lines to the "Puritan." She will be 397 ft. long over all and 88 ft. wide over the guards at the widest part. Inclined compound engines of 5,500 HP. will drive the vessel's paddle-wheels. The freight vessel will have a length over all of 318 ft. and will have vertical triple-expansion engines of 4,500 HP., driving twin screws.

THE SUBMARINE BOATS, "Adder" and "Moccasin," have successfully undergone severe tests of endurance and speed. The "Adder" made a 12-hour run at full speed, averaging 8¾ knots, or ¾-knot more than specified by the Government. This, it should be noted, is an exceedingly long endurance test. The "Moccasin" made a two-mile run submerged at a speed of 7.8 knots, and at the end of the run successfully fired a torpedo, rising but twice during the run to get a view of the target. The officers of the U. S. Navy are reported to have been highly pleased with the efficiency of these Holland boats.

APPOINTMENTS TO THE ISTHMIAN CANAL COMmission will not be considered by the President until the diplomatic negotiations with Colombia are concluded, according to a Washington dispatch to the New York "Journal of Commerce," quoting Senator Cullom as authority. This statement directly contradicts the rumors which have circulated during the past six months as to this or that man having been selected for the Commission.

THE 16-IN. COAST DEFENSE RIFLE, which has been under construction at Watervliet arsenal since early in 1898, was shipped from the gun shop on Nov. 28. The gun, which weighs 130 tons, is 49 ft. long, 5 ft. 4 ins. in diameter at the base and 2 ft. 4 ins. in diameter at the nozzle, was taken from the shop to the water front on two cars and was there lifted by a Merritt-Chapman wrecking derrick to the deck of a barge, which will support two-thirds of its weight, while the derrick, which will float alongside, carries the other third. The barge and derrick were successfully towed down the Hudson by a large tugboat and are now at Erie Basin, New York City, waiting for arrangements to be completed for the reception of the gun at its future station at Sandy Hook.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a collision between a fast passenger train and a freight train standing on a switch, which occurred at Carton, Pa., on the Baltimore & Ohio R. R., on Nov. 30. The collision wrecked both engines and one car; killed the engineer of the passenger train, and injured three others of the two train crews. The accident is thought to have been due to failure to close the switch after the freight train had taken the siding.

A DISASTROUS BOILER EXPLOSION occurred Nov. 29 at the power house of Swift & Co., at the Chicago stock-yards, killing 13 men and injuring 20 others. The boiler was one of a battery of ten tubular boilers, said to have been built only about two years ago, and built at the company's boiler shop. Among the killed were the engineer, the water tender and several firemen, so that it will be almost impossible to ascertain the conditions which existed at the time of the explosion. According to evidence in the Chicago "Tribune" the engineer had several times complained about the employment of incompetent help. The wrecked boiler was taken to the company's shops and locked up ready for inspection by the jury and boiler experts. The following statement is from the "Tribune":

As it stood in the shop, the boiler was upside down. The top had been split from end to end by the explosion, and both heads were blown outward and torn away from the shell. The line of the long rent was ragged, but the edge of the break was sharp and clean cut the entire length. Everywhere the break looked new and bright and nowhere could any sign of a flaw be found.

While the examiners were slow to express an opinion as to the cause of the explosion, it was generally agreed the beginning of the break had been at the top at the rear manhole. From this start the heavy iron had been cleft to the rivetings around the heads until the opening was the width of the boiler.

It is also stated that the boiler and the adjacent one were washed out on the day of the explosion, and after the manhole had been fastened on, the foreman of the washers informed the water tender (who was killed) that the boilers were ready. The accident happened about an hour after this.

A 150-MILE TRANSMISSION LINE on steel towers is planned for the Guanajuato Power & Electric Co., at Guanajuato, Mexico, by Mr. Robert McF. Doble, consulting engineer, of San Francisco, Cal. The steel towers will, it is stated, be spaced 440 ft. apart and the conductors will be 19-strand copper wire cables, equivalent in conductivity to No. 1 solid copper wire. The line voltage is to be 60,000. The power plant will consist of Pelton wheels operating under a head of 320 ft., and 1,500 KW. generators.

AN IMPORTANT PATENT DECISION has just been rendered by the United States Circuit Court for the southern district of New York, in an opinion by Judge Lacombe. The case under litigation was an action for preliminary injunction brought by the Westinghouse Electric & Mfg. Co., of Pittsburg, Pa., against the Orange County Gas & Electric Co., of New York, which latter company was using certain alternating-current transformers, Types "AO" and "G," made by the Stanley Electric Mfg. Co., of Pittsfield, Mass. The question involved was the validity of a patent issued to William Stanley and owned by the complainants. It is said that the suit in reality was the beginning of an attack on the independent electrical manufacturers by the General Electric and Westinghouse companies, who control the larger number of American patents on electrical apparatus. Had the injunction been granted (it was denied), the manufacture of transformers by others than the complainants would have been greatly embarrassed.

The main interest in the case, however, is the question of patent construction involved. The present decision of Judge Lacombe rests on a previous decision of the Circuit Court of Appeals of the same circuit. The claims of the patent are for a combination which includes primary and secondary coils, and in which the primary coil is given "such length of wire exposed to magneto-electric induction that when operated by the dynamo with which it is used, under certain conditions, certain results will follow." The claims of the patent do not state what this length is or how it may be determined; but in the specification of the patent a rule, the so-called "Stanley rule," is given for this purpose. The court then held that

when the patentee in his claim enumerates as one element of his combination a wire of a length which will accomplish the result sought to be achieved, and his patent discloses a method for determining that length with mathematical exactness, his claim may fairly be sustained for the length thus shown, although it might be that some other length covered by the language of the claim, but not of the rule, would fall outside the claim.

That is to say, the language of the claim was so general that it covered a combination to produce certain results; the specification, however, defined one such combination. The patent was held by the court to cover this exactly-defined combination alone, and not any other combination which would not suit the definition and would yet produce the stated result. It should also be noted that the court held that such a length of wire (as given by the rule) was covered by the patent, no matter whether or not the rule itself was used in finding that length.

In the present case before Judge Lacombe, it was shown by "repeated and concurrent testimony of the many experts called by the defendant" that the length of wire used in the primary coils of the transformers in question was substantially different from such length determined by the Stanley rule. As this is the very exception to the patent suggested in the opinion of the Circuit Court of Appeals, viz., "some other length covered by the language of the claim, but not of the rule," Judge Lacombe held that there was no infringement of the patent, and the motion for injunction was therefore denied.

A DRAINAGE CANAL for the Calumet district is proposed by Mr. Isham Randolph, Chief Engineer of the Chicago Sanitary District, and the main drainage canal. The canal would be about 18 miles long and 70 ft. wide, extending from the Calumet River through the Sag Valley to the main drainage canal. The cost is estimated at $11,880,000. With this new canal built, the sewage-laden Calumet River would flow west to the drainage canal, and relieve the lake from its present pollution. With the present canal preventing pollution from the Chicago River, the intercepting sewers (now under construction) preventing pollution from the sewers now discharging along the lake shore, and the proposed canal preventing pollution from the Calumet River, the city might rely upon a pure water supply from the lake. At the present time the water is more or less dangerous in spite of the expenditure of $30,000,000 on the main drainage canal.

ASPHALT LAID ON OLD GRAVEL STREETS is to be tried at New Orleans, La., an appropriation of $1,000 having been secured for an experimental block by Mr. W. J. Hardee, M. Am. Soc. C. E., City Engineer. We are indebted to Mr. Hardee for the following statement regarding the test:

There are streets in this city upon which were laid, some six or eight years ago, a gravel pavement formed of a subgrade of 1 × 12-in. cypress plank and 12 to 15 ins. of compacted gravel, placed in 6-in. layers, sprinkled, and successively rolled with a heavy steam roller. The gravel was obtained from the hills in Mississippi, about 150 miles north of New Orleans, on the line of the Yazoo & Mississippi Valley R. R. Co., at a place called Rosetta, from which the gravel derives its name. The amount of gravel in the mass varies from 50% to 75%; the complement is a stiff clay possessing sufficient cementive properties to form a fair concrete when the mass is compacted. The pavements referred to have, in the general case, proven satisfactory, but because of their perishable character have been very expensive to maintain; the surface of nearly all of them has from neglect become badly worn, and so cut up with ruts as to make travel anything but comfortable. The pavements must now be repaired, and as repairs would be expensive, and under the most favorable circumstances but short lived, it occurred to me that the top might be stripped and the subsection employed as a foundation for an asphalt pavement in lieu of the usual concrete foundation. It so happens that nearly every one of the gravel pavements are situated in the residential section of the city where the traffic is light, both as to amount and weight, particularly weight, it seldom occurring that the streets are used by any other than light driving vehicles. If the experiment proves successful, not only will many thousands of dollars in the near future be saved to the city of New Orleans and the taxpayers, but the rapid extension of modern street paving will also follow, because it is quite certain that a large number of streets now paved with gravel will be repaved with asphalt, coincidentally with the construction of the sewer and water systems that the city will shortly introduce.

A SCOTTISH CENTRAL ELECTRICITY SUPPLY system, which has been authorized by Parliament, will soon be constructed. It is to be located in the district immediately surrounding the city of Glasgow, and its purpose is to generate power cheaply and supply it by electric transmission to various factories and works located along the River Clyde in the vicinity. Three central stations are planned, two of which, at Yoker and Motherwell, will be built at once and equipped for a capacity of 4,500 HP. each. The ultimate capacity is expected to be 10,000 HP. at each of these stations, and 5,000 HP. at Crookston, the third station. The three stations will be located close to coal mines, so that the power can be generated at very low cost. The Clyde Valley Electrical Power Co. is the name of the concern which will build the system; Messrs. Strain & Robertson are engineers for the company. The electrical machinery will be supplied by the British Westinghouse Electric & Mfg. Co.

MODERN TURBINE PRACTICE AND THE DEVELOPMENT OF WATER POWERS.*

By John Wolf Thurso, Civil and Hydraulic Engineer.†

(With two-page plate.)

I. The Development of the Turbine.

The turbine may be called a theoretical invention, as it is one of the few machines which have been invented as the direct outcome of mathematical investigation, and not by experiment, like the steam engine and others, and its further evolution in Europe has always been based on theory. In America, however, turbine construction has been developed almost solely by experiment.

TURBINE DEVELOPMENT IN EUROPE.

Although most of the early turbines were of the radial flow type, the parallel flow turbine soon became the standard type of European builders, and remained so until a few years ago, while the radial flow turbine was rarely used, except for segmental feed turbines, working under high heads.

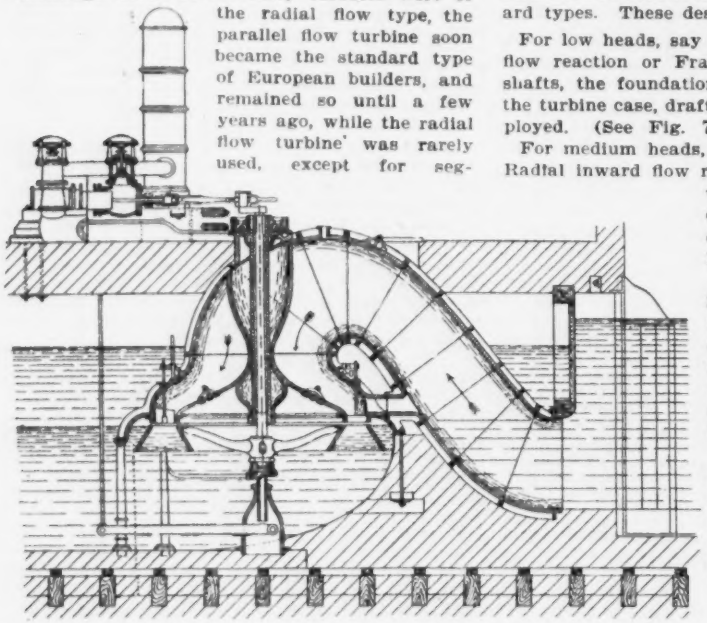

Fig. 1.

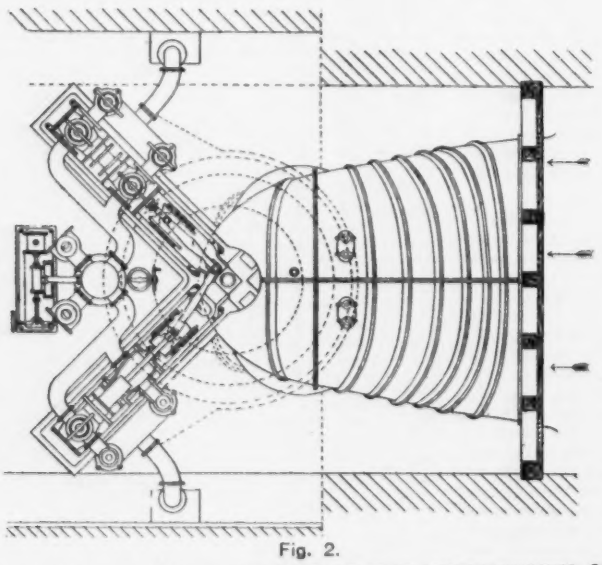

Fig. 2.

FIGS. 1 AND 2. 50-100-HP. TURBINE AT THE WATER-WORKS OF GENEVA, SWITZERLAND.
Built by Girard & Callon, Paris, France.

An interesting example of the parallel flow type is the turbine at the water-works of Geneva, Switzerland, shown in Figs. 1 and 2.‡ This turbine drives two plunger pumps with vertical crank shaft, and develops from 50 to 100 HP. under a head varying between 16½ and 35½ ins., running from 9 to 16 revolutions per minute and using from 530 to 706 cu. ft. of water per second. The siphon-feeder was employed to save tail race excavation, which is in hard rock, as without the siphon the turbine would have to be set much lower. The efficiency is naturally low for such small heads, as the mechanical losses are great in proportion to the power developed. This turbine and pumps, with a head of 16½ ins., have a combined efficiency of 48%, or say 58% for the turbine alone.

Parallel flow turbines are simple and cheap, but no satisfactory way of regulating their speed could be found, and with the advent of electrical transmission, requiring close regulation and higher speeds, builders cast about for a new type of turbine. A great variety of new designs were then brought forward, and while as yet none have been definitely and generally adopted, some of the designs used by the most progressive builders are certain to be soon recognized as the coming standard types. These designs are:

For low heads, say up to 20 ft.: Radial inward flow reaction or Francis turbines with vertical shafts, the foundation masonry usually forming the turbine case, draft tubes being frequently employed. (See Fig. 7.)

For medium heads, say from 20 ft. to 300 ft.: Radial inward flow reaction or Francis turbines with horizontal shafts and concentric or spiral cast-iron cases with draft tubes. (See Figs. 13 to 21.)

For high heads, say above 300 ft.; Radial outward flow, full or segmental feed, free deviation turbines, with horizontal shafts and cast or wrought-iron cases, frequently with draft tube. (See Figs. 3 and 4 and 25 to 27.)

A modified Pelton wheel has of late been gaining in favor, and it is most likely that the type ultimately adopted for high heads will be a combination of the best points of the segmental feed free deviation turbine and the Pelton wheel. (See Figs. 28 to 35.)

As the parallel flow turbine has practically been abandoned, the following refers to radial flow turbines only.

Of all European countries, Switzerland, having many excellent water powers and producing no coal whatever, ranks highest in progressive turbine building, being closely followed by Germany, Austria and Italy. France, although the native country of the turbine, and rich in water power, has advanced little during the last ten years, except that some builders are closely copying American turbines, such as the Hercules. Most of the turbines installed in important French plants are supplied by Switzerland.

The application of the laws of hydraulics to the action of water in simple radial or parallel flow turbines being well understood since early in the nineteenth century, the highest possible hydraulic efficiencies could be calculated for the different types of turbines, and multiplying these values, which vary between 0.80 and 0.90 for the usual designs, by the highest possible mechanical efficiency of the turbine under consideration, the limit of the possible total efficiency is found. This limit, which may be considered to lie between 0.75 and 0.85 for practical working types, has been reached, or very closely approached, with three-quarter to full gate opening at least, by the regular turbines, such as the best European builders have turned out during the last twenty years or more. Their present efforts are, therefore, to make the turbine a complete and self-contained machine, to improve the details such as gate rigging, bearings, etc., to raise the speed for turbines working under low heads, and, as has been the endeavor for a long time, to improve the efficiency of reaction turbines, when running with part gate.

It may here be noted that the term "gate" or "gate opening" is often used to mean the amount of water flowing through the turbine as a per cent. of the quantity of water passing through it, when working with full capacity or full gate opening. It will be seen that the term is to some extent ambiguous, because (except with full gate) the percentage or fraction of the gate that is open for the passage of water is smaller than the percentage or fraction of the water actually flowing through the turbine.

For free deviation turbines, the question of efficiency at part gate has been so well solved that further improvements are not to be expected. Efficiencies of 70% for 0.2 gate opening to 80% for full gate, are well within the common practice, and these results have been reached by very simple means. With full turbines, an ordinary cylinder gate is used, as shown in Figs. 25 to 27, reducing the outflow openings of all guide buckets equally, in proportion to the decrease in power

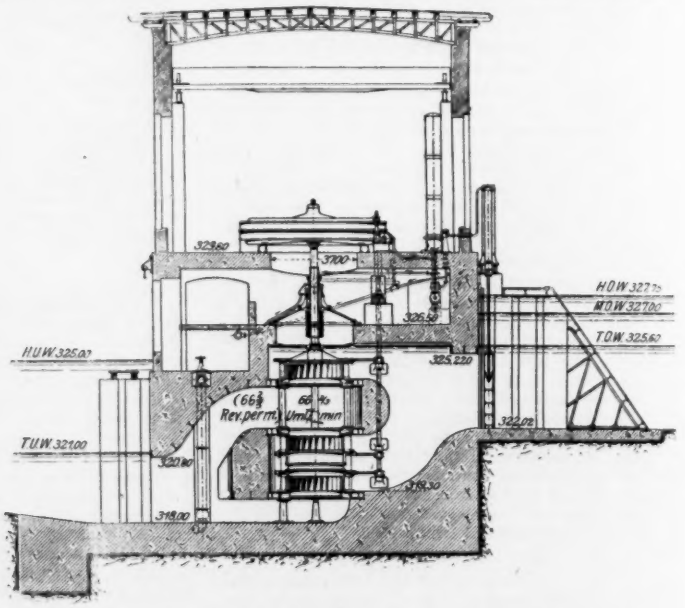

FIG. 7. CROSS-SECTION OF POWER HOUSE OF THE ELEKTRIZITAETSWERK BEZNAU, BEZNAU, SWITZERLAND.
Turbines built by Th. Bell & Co., Kriens, Switzerland.

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†75 Common St., Montreal, Can.

‡The writer is indebted to Mr. T. G. Gossler, E. E., General Superintendent of the Montreal Light, Heat & Power Co., for a drawing of the Chambly plant, from which Fig. 12 was made; to Messrs. Stilwell-Bierce & Smith-Vaile Co., Dayton, O., for drawings, from which Figs. 22 to 24 were made, and to Messrs. I. P. Morris, Philadelphia, Pa., for a cut from which Figs. 40 and 41 were made. Figs. 1 and 2 are reproduced from G. Meissner, "Die Hydraulik und die hydraulischen Motoren," Vol. 2, Jena, 1896-97. Figs. 8 to 11 and Fig. 42 are reproduced from "The Canadian Engineer." Figs. 3 to 7, 13 to 21, and 25 to 39 are reproduced from "Zeitschrift des Vereins Deutschen Ingenieure," Berlin.

developed, while with segmental feed turbines a slide is employed, as shown in Figs. 23 and 24, which closes the outflow opening of one guide bucket after the other, as the load on the turbine is reduced.

Greater difficulties, however, are met with, when it is attempted to regulate reaction turbines, so as to show high efficiencies with partial loads. The simplest means are in this case the most wasteful, and have practically been abandoned, but may be mentioned here, viz., the throttling of the water in the inlet pipe or in the draft tube, by a butterfly valve (see Figs. 40 and 41), or at the lower end of the draft tube, by a cylinder gate, closing the annular space between the draft tube and the bottom of the turbine pit. For high heads and very long penstocks or feeder pipes, a by-pass was used in connection with the throttle valve.

The two methods of regulating reaction turbines, most widely used in Europe at the present time, are as follows: (1) the vanes, forming the guide bucket, or else a part of each vane, is made movable, so that the size of each of the clear openings between the vanes can be altered simultaneously in accordance with alterations in the load of the turbine, but the curvature of the guide bucket, and with it the course of the water, remains the same or very nearly the same (see Figs. 13 to 21). (2) The depth of the guide and runner buckets or the distance between the crowns, are divided into two or more spaces by additional crowns, thus forming two or more turbines, which are regulated by one common cylinder gate. Thus a triple—or three-story—turbine, when working with one-third or two-thirds gate, has one or two turbines working with full gate and full gate efficiency, while the two turbines or one remaining are shut off entirely.

The ideal regulation of reaction turbines would be the simultaneous altering of the size of all the clear openings of both the guide and the runner buckets, in accordance with alterations of the load, and without changing the curvature of the buckets. This could be attained by making one crown of each, the guide and the runner, movable, so that the size of the bucket openings could be varied by varying the distance between the crowns, but all attempts to carry this out in practice have so far failed.

However, even with the imperfect gate arrangements, the following efficiencies are now commonly realized with reaction turbines:

Gate opening	0.2	0.4	0.6	0.8	1.0
Efficiency	60%	70%	75%	80%	78%

It should be noted here that the highest efficiency of reaction turbines is usually found to be between 0.8 and 0.9 gate. opening

Free deviation turbines must, for good efficiency, work in the free air; that is, above and clear of the tail water. Therefore, to enjoy the advantages of a draft tube with this class of turbines, they are now furnished with an air admission valve, which automatically regulates the water level in the turbine case or draft tube, so as to keep it just below and clear of the turbine runner. (See Figs. 23 to 27.)

The difficulty presented by the end thrust of single Francis turbines, especially troublesome in connection with high heads, has been successfully overcome by European builders, by having part of the cast-iron turbine case form an annular chamber, open towards the runner, which revolves in front of it, the chamber being connected with the penstock by a pipe. By means of an ordinary gate valve, the pressure in the chamber and with it the end thrust, can be so regulated that the shaft will press against the step bearing with just enough force to prevent any end motion. (See Figs. 13 to 17.)

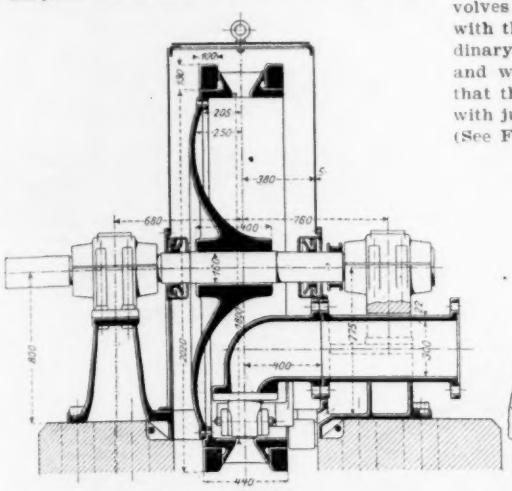


Fig. 3.

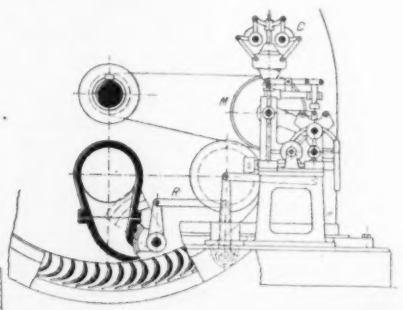


Fig. 4.

FIGS. 3 AND 4. 1,000-HP. TURBINE FOR THE WALLISER INDUSTRIE-GESELLSCHAFT, VERNAYAZ, SWITZERLAND.
Built by Piccard, Pictet & Co., Geneva, Switzerland.

Radial outward flow turbines can either be designed to have no end thrust whatever, and turbines on horizontal shafts are usually arranged in this manner (see Figs. 3 and 4 and 23 to 27), or to have any desired amount of end thrust, up to the limit set by the head of the water and the size of the turbine. Such end thrust is often employed to support the weight of the rotating parts of turbines on vertical shafts. As an example may be mentioned the 5,500-HP. turbines at Niagara Falls, N. Y., where the lower turbine of each pair has no end thrust, while the upper one has an upward thrust, which carries the runners, shaft and rotating field, weighing together about 80 tons. The easy working of these turbines is well illustrated by the fact that without load they will run at a speed of 40 revolutions per minute, with the turbine gates entirely closed and only using the water which leaks through the small clearance space between the runners and the gates, which clearance is only 1-16-in. If it is desired to stop the turbines without closing the head gates, a brake has to be applied to bring the turbines to rest.

In general it may be said that European builders have brought out and perfected a number of turbine types, which have enabled them to meet any reasonable conditions, and to predetermine and guarantee a high efficiency in all cases; for the small turbine of a few horse-powers as well as for those of 5,500 HP. at Niagara Falls, and for the head of 16½ ins. used at Geneva, Switzerland, as well as for the highest heads, such as those used at Vernayaz, also in Switzerland, where the six turbines at the electric power station are developing 1,000 HP. each, under a head of 1,640 ft. One of these turbines is shown in Figs. 3 and 4. As will be noted, the turbine is of the free deviation type, and has but one guide-bucket. The peripheral speed of the runner is normally 184 ft. per second, but should the governor fail to act, with no load on the turbine, this speed may run up to twice as much, or 368 ft. For this reason two heavy steel rings are shrunk on to the runner, which at the same time aid the regulation by acting as flywheels.

TURBINE PUMPS.

Although not strictly belonging to the subject of this paper, it may be of interest to mention here the reversed turbine or turbine centrifugal pump, which, like the turbine itself, was evolved by theoretical studies.

Turbine designers reasoned correctly that when a turbine with a certain head and quantity of water gives a certain horse-power and number of revolutions, then a similar turbine, being driven from some outside power at the same speed, but in opposite direction, will act as a pump, elevating the same quantity of water to the same height and requiring the same horse-power as was developed by the machine when used as a turbine. Of course, allowance has to be made in practice for the losses in both the turbine and the pump, but still some remarkable results have been obtained with such turbine pumps.

While theoretically all turbines could be reversed, the radial inward flow type was naturally chosen, and the buckets and other water passages were somewhat modified in shape, as the direction in which the water flows through the pump is opposite to that in which it flows through the turbine. The turbine runner acts as the fanwheel of the pump and the guide buckets convert the speed of the water, imparted to it by the fanwheel, into pressure, and it is this application of the guide buckets which constitutes the great improvement and permits the turbine pump not only to work economically against heads, considerably higher than could ever be attempted with the ordinary centrifugal pump, but also to give a much better efficiency than can be obtained with the ordinary pump.

For comparison, it should be stated here, that the ordinary centrifugal pump shows a maximum efficiency with a lift of about 17 ft., this efficiency being between 50% and 65%, according to the shape of the fanwheel and case and the size of the pump.

A number of turbine pumps, shown in Figs. 5 and 6, were recently built and tested in Switzerland, each having four fanwheels in one case, arranged in series; that is, the first fanwheel discharges into the suction of the second one, and so on, the water successively passing through all wheels. These fanwheels have a diameter of 20 ins., and with 890 revolutions deliver 1,010 U. S. gallons of water per minute against a head of 428 ft., which is equal to 107 ft. of head for a

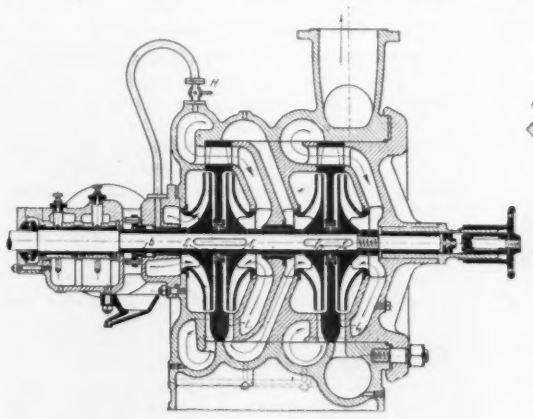


Fig. 5.

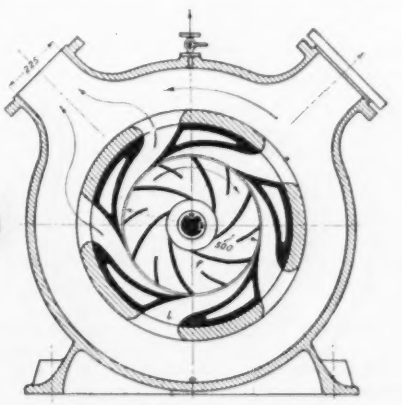


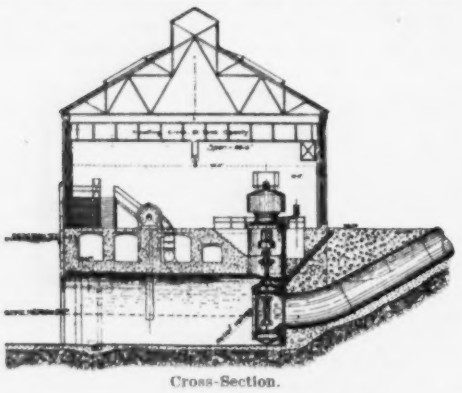
Fig. 6.

FIGS. 5 AND 6. QUADRUPLE TURBINE PUMP.
Built by Sulzer Bros., Winterthur, Switzerland.

pump with single fanwheel, and give an efficiency of 76%, certainly a great advance in the construction of centrifugal pumps.*

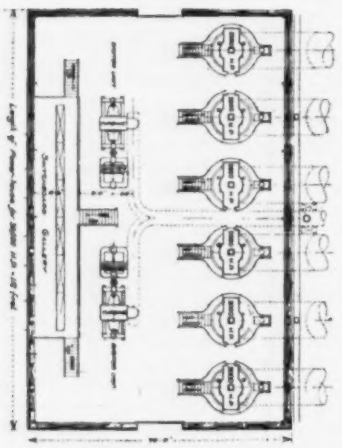
TURBINE DEVELOPMENT IN AMERICA.

In the United States, the development of the turbine has been entirely different from that in Europe. In 1834, Mr. Fourneyron, a French engineer, had brought out the radial outward flow turbine known under his name, and in 1840, Mr.



Cross-Section.

Fig. 8.



Plan of vertical arrangement

Fig. 9.

Figs. 8 and 9. Proposed Vertical Arrangement of Turbines for the Power House of the Shawinigan Water & Power Co., Shawinigan Falls, Que.
Designed by T. Pringle & Sons, Engineers, Montreal.

Area occupied by power house: Horizontal, 18,400 sq. ft.; vertical, 7,840 sq. ft.

Increased cost of horizontal over vertical arrangement:

On excavation, at $1 per cu. yd.	$9,740
" concrete and floors, at $8 per cu. yd.	40,000
" penstocks, at $55 per running ft.	10,000
" Building, brick, roof, windows and heating plant	5,420
	$65,160

U. A. Boyden, of Massachusetts, commenced to study and to improve upon this type, being soon followed in this work by Mr. James B. Francis. In 1849, however, Mr. Francis built a radial inward flow or vortex turbine for the Booth Cotton Mills, Lowell, Mass. This turbine, which worked under a head of 19 ft., and, when tested, showed an efficiency of 79.7%, or practically 80%, may be regarded as the prototype of all American turbines.

The number of revolutions varies as the square root of the heads employed and for the same head, the revolutions of different turbines are inversely proportional to their diameters. As all the early turbines were used with low heads, about 20 ft. or less, and as already then, as now, the tendency was to increase the speed of shafting and machinery, builders naturally reduced the turbine diameter.

Mr. Francis' turbine was of the plain inward flow type, with sufficient room in its interior for the water to turn and escape axially. With the continued reduction of the turbine diameter, this interior space became more and more reduced, so that it soon became necessary to turn the water into an axial direction while still in the runner bucket, or in other words, to curve the bucket from a radial to a more or less axial direction. This has been going on gradually, as can be seen by comparing the early forms of the Humphrey and the Swain turbines with the present form of the Hercules, New American, Victor, Leffel and other turbines, which have scarcely more interior space than is required to pass the shaft through and have a much greater part of the runner buckets in the axial or parallel flow direction than in the radial flow direction, while the runner buckets have assumed such an intricate shape that it is hardly possible to analyze the action of the water while flowing through these buckets, or to mathematically predetermine their shape for given conditions.

Another consequence of the reduction of the diameter is that the inner ends of the buckets, which closely approach the center of the turbine, are located on a very small circle, which limits their number and gives them a very close spacing, while the spacing on the outer circumference becomes so large, 6 ins. and even 12 ins. being not uncommon, that the buckets are unable to properly guide the water as the best efficiency would demand. The area through which the water enters the runner, being the outer circumference of the runner multiplied by the axial dimension of the bucket entrance, decreases, of course, with the diameter of the runner, and with it and in the same ratio decreases the quantity of water passed through and the power developed by the turbine.

To prevent this decrease in entrance area and power, builders have gradually increased the axial dimension of the bucket entrance. Thus the efforts made towards greater speed and power have transformed the plain inward flow turbine runner of fifty years ago into the shape now generally employed.

The guide buckets have not altered so much as the runner buckets, and of the great variety of gate arrangements that have been tried only the following three have come into general use:

1. The cylinder gate, moving in an axial direction, as used by Mr. Francis with his early turbines, is now by far the most extensively employed gate.

2. The register gate, a rotating cylinder, having slots which correspond with the outlet openings of the guide buckets. This gate is not so much used now as some years ago.

3. The wicket gate, having the guide buckets formed by swinging or otherwise movable blades or vanes. This gate is made in different forms and is next to the cylinder gate the most widely used arrangement.

II. Present American Turbine Practice.

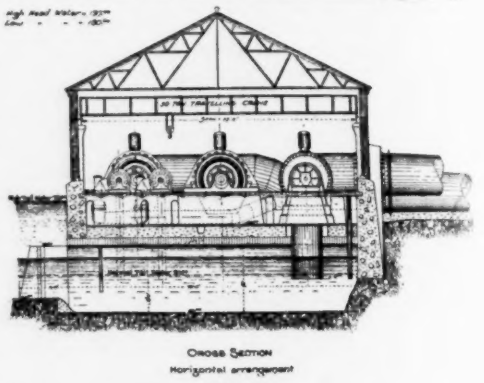
THE TURBINE AS A HYDRAULIC MOTOR.

For low heads, say up to about 40 ft., the American type of turbine has the great advantage over all other turbine types in common use, that it gives the greatest number of revolutions for a given head and power developed, or the greatest power for a given head and diameter of runner, while the American system of manufacturing only one line of turbines from stock patterns has the great advantage of enabling the builders to fill orders cheaply and quickly.

As already stated, the American turbine has been developed solely by experiment, and the testing flume at Lowell, and later on that at Holyoke, Mass., may be called the cradle of the American turbine. However, the greatest head available at both these flumes was but 18 ft., and the turbines have therefore been adapted and perfected for such low heads only, while the builders are almost wholly in the dark in regard to the action of their turbines when used with medium or high heads.

So far as the writer is aware, results of reliable tests of American turbines, working under heads much greater than 40 ft., have never been published; and where such tests have been made, the results have been carefully kept from the public. It appears, nevertheless, that a number of similar American turbines of very large power and working at Niagara Falls, N. Y., under a head of over 200 ft., are giving a maximum efficiency of some 68%, while the turbines designed in Europe and working at the Niagara Falls Power Company's plant are said to give 81% efficiency.

At another well-known power plant, utilizing a head of about 200 ft., the first installation of American turbines gave an efficiency of a little over 40%; the second installation, also of American turbines, but from another maker, gave an



Cross Section
Horizontal arrangement

Fig 10.

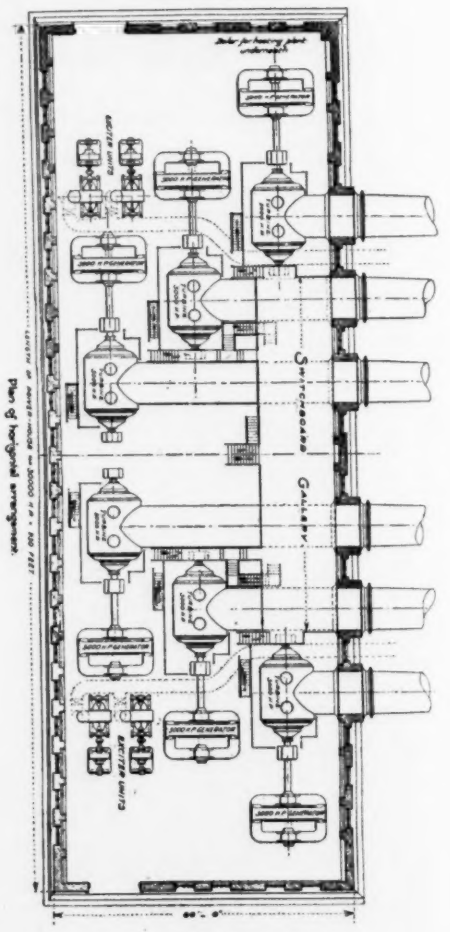


Fig. 11.

Figs. 10 and 11. Horizontal Arrangement of Turbines for the Power House of the Shawinigan Water Power Co. Shawinigan Falls, Que., as Actually Installed.
Designed by W. C. Johnson, C. E., Niagara Falls, N. Y.

efficiency of a little over 60%; while the third installation, which consisted of turbines built in America, but according to European designs, gave an efficiency of nearly 80%.

The low efficiency of the American turbine, when used under high heads, is only what is to be expected, as runner and guide buckets, constructed to give an efficiency of over 80% under a head of less than 18 ft., cannot possibly also give a high efficiency under high heads, such as 200 ft. or even 100 ft. At the same time, high heads, in most cases, have only a limited flow of

*Since the above was written, an illustrated description of a turbine pump has appeared in Engineering News, issue of Jan. 23, 1902.

water, thus demanding a higher efficiency for the turbines employed for their utilization than low heads, where the flow is, as a rule, more abundant. In general it must be said that the high power and speed of the American turbines and the custom of filling all orders from stock patterns, is also against their use in connection with high heads, as may be shown by two examples, as follows:

While making the specifications for some double turbines, each pair to develop 5,500 HP. under 130 ft. head, and at a speed of 250 revolutions per minute, the writer, in speaking to a well-known turbine builder of the Central States, in regard to the matter, found the builder quite willing to bid for and to supply these turbines from his stock patterns. Now, this builder's catalogue shows that a pair of turbines to develop 5,500 HP. under 130 ft. head would make 413 revolutions instead of 250, as required, or that a pair of turbines working under 130 ft. head and running at 250 revolutions per minute, would develop 17,312 HP. The plant was subsequently equipped with turbines of the European type.

A case, showing still more forcibly how little the American turbine is adapted to high heads, is that of the turbines recently installed by the Cataract Power Co., of Hamilton, Ont., and shown in Figs. 13 and 14. These are single turbines, designed and built in Europe, developing each 3,000 HP. under 245 ft. head, and at a speed of 286 revolutions per minute, and give an efficiency of 80%. No doubt many American turbine builders would have been willing to supply the turbines for this plant from their stock patterns, using, of course, a pair of turbines, as otherwise, under this high head, the end thrust would be too great to be properly taken care of. Using the figures given in a catalogue of McCormick turbines, calculations show that a pair of turbines, to develop 3,000 HP. under 245 ft. head, would have a speed of 1,242 revolutions per minute, instead of 286, as required, or that a pair of turbines working under 245 ft. head and running at 286 revolutions, would develop 84,672 HP., or over 28 times the desired amount, and requiring a case 17 ft. in diameter and over 26 ft. long, while the total floor space occupied by the European turbines, up to center of dynamo coupling, is only 11 × 14½ ft.

Evidently the American type of turbines is not adapted to such high heads, yet the head is not high enough to use Pelton wheels to advantage, as may be seen from the following figures, taking the speed of the outside of buckets as $0.5\sqrt{2gH}$, which is the usual practice. To develop 3,000 HP. under 245 ft. head and at a speed of 286 revolutions, would require seven Pelton wheels, each having 4 ft. 5 ins. diameter to outside of buckets and three 3-in. nozzles, or 21 nozzles in all. This would certainly be a very complicated arrangement, especially in regard to the regulation of so many nozzles.

When supplying American turbines for high heads, most builders reduce the power of the turbines by using smaller turbines than required for the desired number of revolutions and then draw the speed down to the proper number, by means of the governor and the gates. If the power of a turbine is very much in excess of the required amount, turbine builders often also reduce the axial dimension of the runner bucket entrance, which, of course, affects the efficiency of the turbine in nearly the same way as would an equal reduction in gate opening, since only the entrance area is changed, while the rest of the runner bucket remains as before.

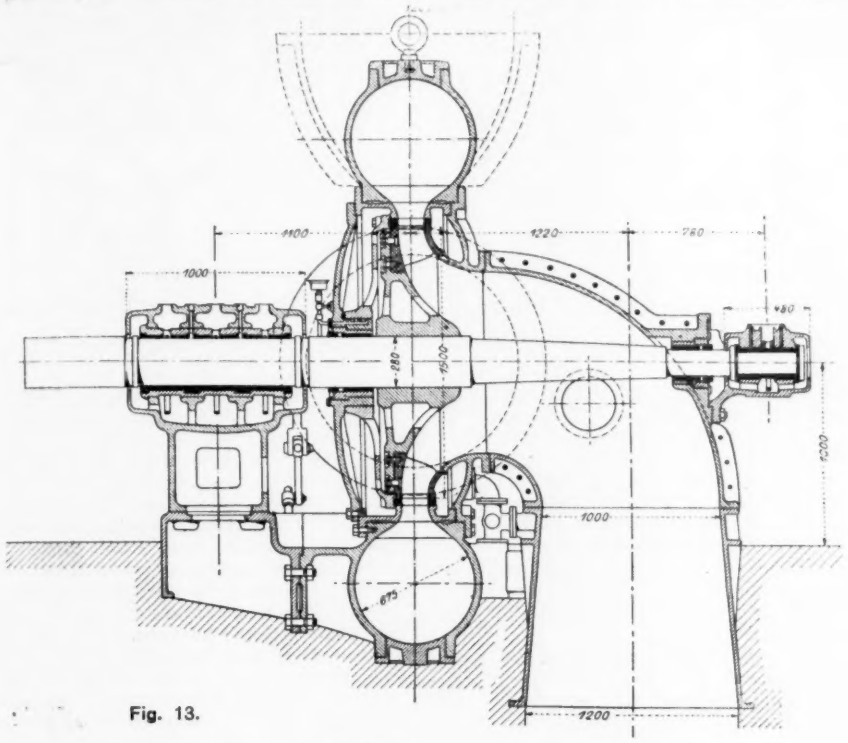


Fig. 13.

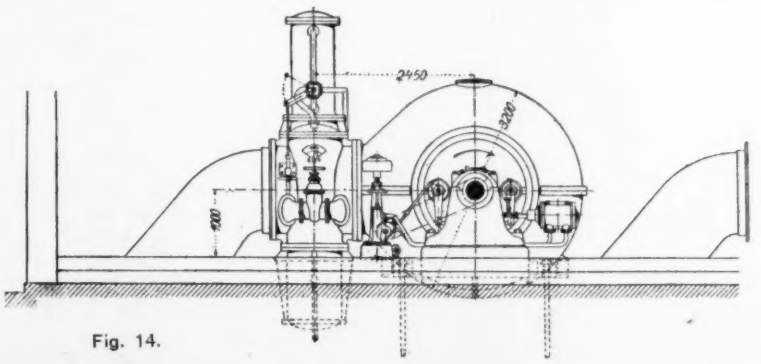


Fig. 14.

FIGS. 13 AND 14. 3,000-HP. TURBINE FOR THE CATARACT POWER CO., HAMILTON, ONT.
Built by A. Riva, Monneret & Co., Milan, Italy.

The use of the American turbine in connection with high heads or where special conditions have to be met, can thus only be regarded as a makeshift, and turbines of the European type will be preferred in all cases where time and money required for their installation are available, as is shown by the plants of the Niagara Falls Power Co. and the East Jersey Water Co., in the United States, and the Cataract Power Co., already referred to, the Shawinigan Water & Power Co., and the plant at Montmorency Falls, in Canada. It is a matter for wonder that American turbine manufacturers will not supply turbines of the European type, where the conditions make their use advisable; but the writer found it practically impossible to induce builders to bid on anything else except the American standard type, even when they were furnished with complete drawings and relieved of all responsibility in regard to the performance of the design. Of course, the writer is aware that some manufacturers make a special high pressure turbine, but except those built by one firm these machines need not to be considered here as the guides and runners are the same as those of the regular American turbine, the only difference being in the general arrangement.

THE TURBINE AS A MACHINE.

So far the American turbine has only been considered as a hydraulic motor, but it may be well to consider it also as a machine.

Turbines have not yet come to be regarded as important machines, and builders therefore employ in their construction such materials and workmanship as are only used for second and third-class machinery, in sharp contrast to European practice, where turbines are constructed with the same care as high-class steam engines.

For installations with vertical turbines, the builders, besides furnishing the turbine proper, can only prepare plans and give advice in regard to the general arrangement, while the choice of material and workmanship rests with the purchaser of the turbine. One sees, therefore, a great variety of settings, from the crazy wooden flume, stuck to the outside of a dilapidated mill, to the modern concrete and steel construction.

The use of turbines on horizontal shaft, made possible by the use of the draft tube, has been rapidly increasing during recent years, and while this arrangement means a very great advance in general, practically no improvements have been made in the constructive details of horizontal turbines over those set vertically.

The case for such turbines consists usually of cast-iron heads and a shell made of low quality steel plate, barely thick enough to withstand the interior water pressure and having two light steel I-beams fastened along its bottom, supposed to stiffen the whole. The turbines themselves and such main bearings and gate shaft bearings as are located inside of this case, are held in place and fastened to or braced against the thin shell plate by cast-iron or gas-pipe supports. The regulating gate rigging and other parts are often bolted or riveted to the outside of the shell, while the outside main bearings are either carried on little shelves cast onto the heads of the case, or are bolted to the draft tube elbow or elbows, or supported by yokes, resting on the above-mentioned I-beams.

It is only reasonable to assume, especially when it is considered that the rivet and bolt holes in the plates, forming the case, are often badly matched, and the drift pin is freely used during erection, that the water pressure in the case due to the head under which the turbine is working, will somewhat alter the shape of the case from what it is while the case is empty, in which state, of course, all assembling, riveting, bolting and adjusting was done, and this alteration of shape must naturally throw everything that is fastened to the case out of alinement, besides setting up stresses not provided for in the design.

The incessant surging or oscillating of the water in the penstock or feeder pipe and in the draft tube, due to changes in the gate opening in regu-

lating the turbine, causes the water pressure in the case to alternately rise above and sink below the normal pressure due to the working head. These variations are greatest where long penstocks and draft tubes are used, and they keep the case and everything fastened to it, continually working or moving and under constantly varying stresses, a state of affairs certainly not productive of easy running or long life of the turbine.

plied to a single shaft. It must be said, however, that thrust bearings, to work satisfactorily, must be well designed, of good material, and liberal proportions, and of superior workmanship.

CAUSES OF LACK OF PROGRESS AMONG AMERICAN TURBINE BUILDERS.

The backward state of the art and the scarcity of improvements in American turbine construction is certainly surprising when compared with

It is not for the writer to say, which of the [illegible] are right and which are wrong, but Eu[illegible] engineers maintain, that the difference is d[illegible] the different methods of water measurement [illegible] Holyoke, the old Francis formula for flow of water over weirs is still in use, but this fo[illegible] does not take into consideration a number of tors that have an important bearing on the r[illegible] In Europe the formulæ used for flow of [illegible]

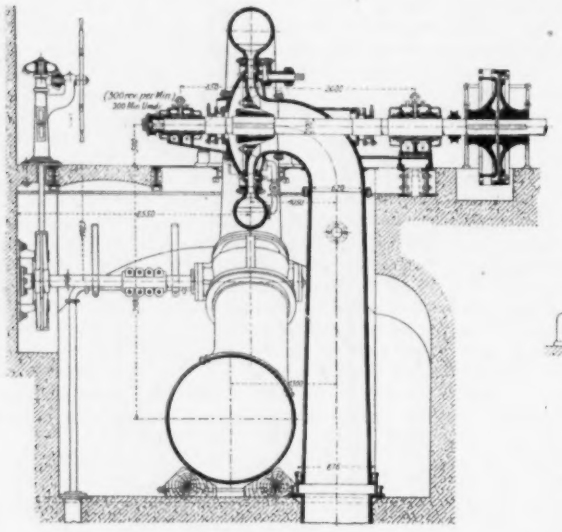


Fig. 17.

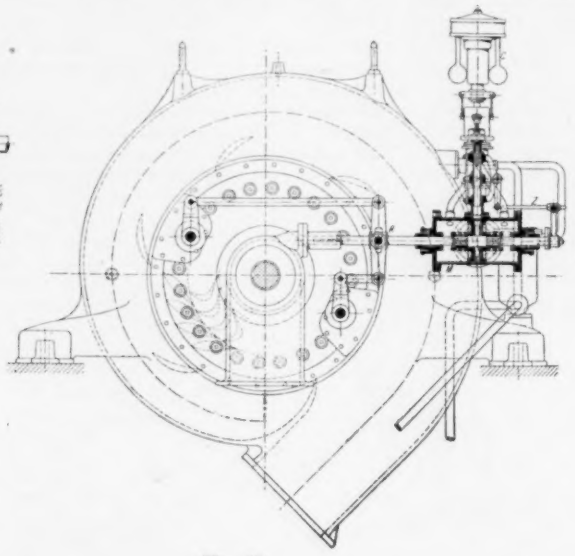


Fig. 15.

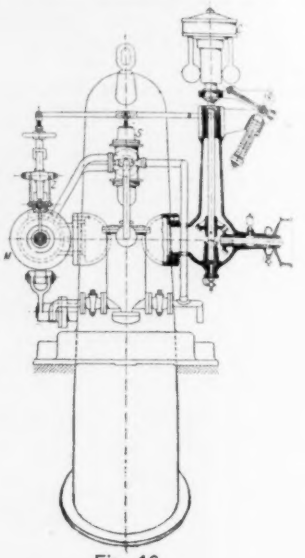


Fig. 16.

FIGS. 15 TO 17. 1,000-HP. TURBINE OF THE BOSNISCHE ELEKTRIZITAETS-AKTIEN-GESELLSCHAFT, JAJCE, BOSNIA.
Built by Ganz & Co., Budapest, Hungary.

When obliged to employ steel plate cases, the writer has mitigated this evil somewhat by using thicker plates and deeper I-beams than were proposed by the builders.

Another fault of steel plate cases is the difficulty of properly shaping them, and in consequence the water, while passing through such cases, is subjected to abrupt changes in direction and speed and to reduce the loss in working head, caused by such changes, the cases are made larger than would be required, if easy waterways could be obtained.

A great number of plants have been installed with two or more turbines in one case and admitting the water through the end of the case. If local conditions make it necessary that the water shall flow towards the turbine in an axial direction, the open masonry flume or turbine chamber would be much the better arrangement; but where circumstances, such as high heads, cost, etc., demand the employment of a case, the latter should be considerably larger in diameter than the diameter of the turbines would otherwise require.

To have thrust and other bearings, gate shafts, gears, racks, guide rollers, set screws and other moving or adjustable parts inside the turbine case, where they cannot be inspected or adjusted, as is now the universal custom with builders, must also be considered faulty construction, the more so as it could be easily avoided.

The size of the turbine shaft, as generally supplied by builders, is barely sufficient to transmit the power generated by the turbine, whereas the shaft should be considerably stronger than the power alone would demand, particularly for turbines on horizontal shafts, and here again a greater excess of strength is required for a pair of turbines on one shaft than for a single turbine.

When ordering a large turbine on a horizontal shaft for a head of 40 ft. or more builders will usually advise the purchaser to use a pair of turbines on one shaft, to avoid the end thrust, while for heads of 80 ft. or more, most builders will decline to assume any responsibility in regard to the thrust bearing, if a single turbine is used, claiming that no such bearing can be made that will properly take care of the end thrust of large single turbines under high heads. This is of course a ridiculous assertion in the face of the daily experience of thousands of ocean steamers, where the whole propelling power is converted into end thrust, and 15,000 HP. and more are applied to a single shaft.

the advanced state to which nearly every other line of machinery has been brought in America. There is this to be said for the turbine builder, however, that he would have very little sale for a high-class turbine. The fault rests chiefly with the purchaser, who generally believes that water-power costs little or nothing, and that any turbine which will turn his machinery is good enough.

It is also very much to be regretted that the practice of testing turbines in the flume at Holyoke has become so universal, as although these tests may give very accurate figures, showing how the efficiencies of different sizes and makes of turbines compare with each other when tested with a head of less than 18 ft., even under the most favorable conditions, they do not give any information whatever about the real or absolute

over weirs are based on the latest investigations on the subject.

As an example may be mentioned the turbine bought by a European builder from one of the largest and best-known turbine manufacturers in the United States, the object being to take up the construction of American turbines, if the high efficiencies claimed could be verified. The turbine was duly tested at Holyoke in the spring of 1900 and retested in Germany in the spring of 1901. The tests in Germany were made by one of the highest authorities on turbines, and the testing flume was equipped with the latest and most refined instruments. The results of the tests show the following efficiencies, expressed in per cent.:

	Tests		
	Holyoke.	German.	Difference.
Full gate	80.65	71.8	8.85
0.321 gate	67.31	58.0	9.31

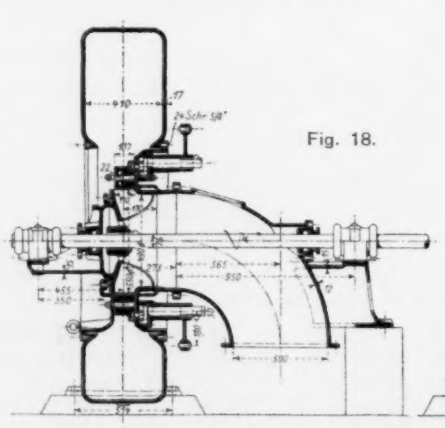


Fig. 18.

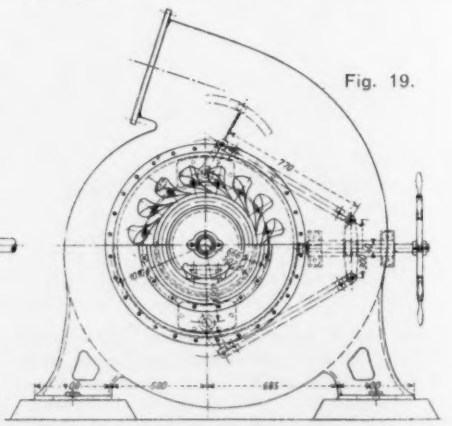


Fig. 19.

FIGS. 18 AND 19. 104-HP. TURBINE BUILT BY THE AKTIEN-GESELLSCHAFT, WINTERTHUR, SWITZERLAND (FORMERLY J. J. RIETER & CO.).

efficiency the turbine will show, when properly set up and connected in its intended place and working under a head perhaps five or ten times greater than that available at Holyoke.

Results of efficiency tests made at Holyoke can also not be compared with results obtained by tests made in Europe, as has been shown repeatedly by having turbines tested at Holyoke and retested in Europe, the latter test invariably giving a much lower efficiency than the Holyoke tests.

The gate here is the actual opening of the gate and not the proportional discharge; 0.321 gate being the smallest opening tested at Holyoke. The total weight on the turbine step was 25% greater during the Holyoke tests than during the German tests.

The tests made at the Centennial Exhibition in Philadelphia, 1876, have never been taken seriously by European engineers.

To test turbines in their place and under working conditions, as is nearly always done in Eu-

rope, would in most cases cost but little more than the Holyoke test, but the results would be immensely more valuable to the purchaser, to the builder of the turbines, and to the engineering profession generally, provided, of course, the tests are made by competent persons.

Two cases may be mentioned to show the slight value of the Holyoke test. A year ago the writer made the contract for some 1,400-HP. turbines, to work under a head of 110 ft., and a well-known

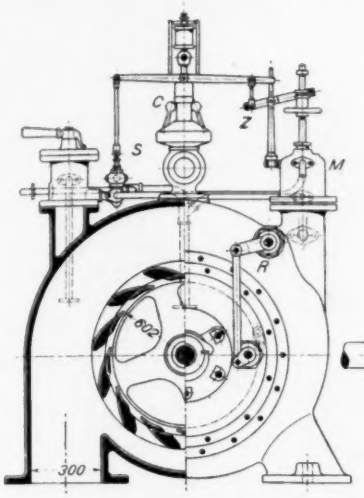


Fig. 20.

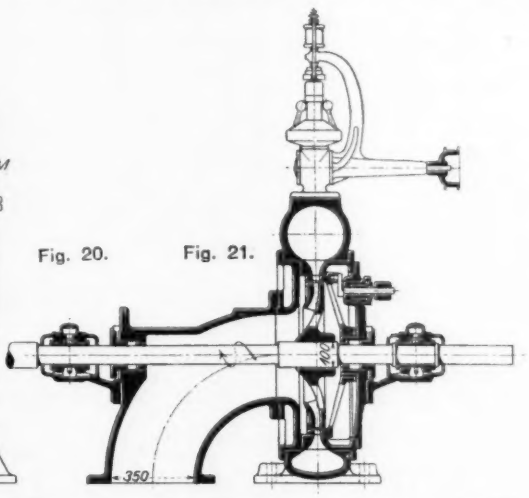


Fig. 21.

FIGS. 20 AND 21. 200-HP. TURBINE BUILT BY ESCHER, WYSS & CO., ZURICH, SWITZERLAND.

builder offered to guarantee 80% efficiency. Upon being informed that the tests were to be made with the turbines in place, he modified his guarantee to 80% at Holyoke, and 73% in place. The other case is that of a large power plant in Canada, using a great number of turbines of the same size and working under a head of 11 ft. The builder guaranteed the customary 80% efficiency, shipped one of the turbines to Holyoke, and was able to show test results of about 83%. The engineers in charge of the construction of the plant in question, took at random a turbine from the lot received and had it tested at Holyoke, but the efficiency was only 72%, and it required a great deal of polishing and improving to bring the efficiency of this turbine up to 80%, and the conclusion is naturally that only the two turbines tested are up to the guaranteed 80%, and all the rest have an efficiency of about 72%.

The importance of a high efficiency in cases where water is bought or power sold may be easily shown. Supposing the water required to develop one gross or theoretical horse-power costs ten dollars per year, which is about the average of prices paid in the New England States, then the net or effective horse-power costs $14.30 with 70%, and $12.50 with 80% efficiency of turbines, or a saving of $1.80 per effective horse-power in favor of the turbine with the higher efficiency. With 5% interest on capital invested and 10% for depreciation, taxes, etc., or a total of 15%, which is very high, the above $1.80 would pay the interest on $12.00, or in other words, the turbine giving 80% efficiency could cost $12.00 more per horse-power, or a 1,000-HP. turbine could cost $12,000 more, than a turbine giving only 70% efficiency, without increasing the cost per effective horse-power per year. As a 1,000-HP. horizontal double turbine of the usual type, and for 80 or 100 ft. head costs complete with case and draft tube, and erected in place, about $6,000, and will give about 70% efficiency, a properly designed and built turbine, giving 80%, could cost $18,000 without being more expensive than the other; but as such a turbine could be bought for about $10,000 the higher-priced turbine really means a saving in capital invested to the amount of $8,000, or $8 per horse-power.

Or supposing that power is sold at $15 per year for one effective mechanical horse-power at the turbine shaft and that the water supply is limited. The amount of water required to develop one effective horse-power with 70% efficiency will give 1.143-HP., worth $17.14 per year, with 80% efficiency. The difference of $2.14 in favor of the turbine with the higher efficiency is equal to an interest of 15% as above, on $14.27, or a 1,000-HP. turbine giving 80% efficiency could cost $14,267 more than a turbine giving 70% without being more expensive.

Other causes that have retarded the progress in turbine construction may be mentioned, such as the belief of purchasers that the turbine is a very simple machine, and that they know all about it, and therefore do not need the service of a hydraulic engineer; that the few hints given in turbine catalogues are all that is necessary to know, and that any third-class machinist or millwright who has once helped to install a turbine is a competent hydraulic engineer. That the ignorance of the purchasers in regard to turbines is well known to builders is shown by the unreasonable claims and statements made in turbine catalogues.

But hydraulic power engineers, where consulted in connection with water-power developments, are also often to blame for not properly explaining to their clients the advantages of a high-class turbine, and the turbine specifications prepared by engineers are, as a rule, poor, superficial and insufficient, and no effort is made to ascertain whether the specifications have been complied with or not. It may be said that there are many so-called hydraulic engineers who do not know any more about turbines than what they can learn from builders' catalogues, and who apparently have not the least idea that anything better can be produced in the line of turbines than is generally furnished by the builders.

Another reason that turbines have advanced so little in America, and that their design has not yet been placed upon a scientific basis, is the lack of attention paid to the subject by the engineering schools and the want of an up-to-date text-book on turbine design. In all European colleges, the theory and the design of turbines is taught with the same care as the theory and the design of steam engines, while in many American colleges, it seems, the theory of turbines is only casually mentioned in the lectures on the flow of water, while turbine design is not taught at all.

III. Modern Turbine Types and Their Construction.

Taking into consideration all the faults of the present American turbine practice, the increased use of turbines in general, and of turbines for driving dynamo machines in particular, the necessity of radical improvements will be apparent. The writer would therefore suggest that turbines should be designed and built with the same care that is given to other high grade machinery, and further, that three distinct types of turbines be adopted. The type to be employed in each individual case should be in accordance with the height of the head to be utilized as follows:

1. Low heads, say up to 40 ft.: American type of turbine on horizontal or vertical shaft in open flume or case, nearly always with draft tube.

2. Medium heads, say from 40 to 300 or 400 ft.: Radial inward flow reaction or Francis turbine with horizontal shaft and concentric or spiral cast-iron case with draft tube.

3. High heads, say above 300 or 400 ft.: Pelton wheel or radial outward flow, segmental feed, free deviation turbine, or a combination of both, on horizontal shaft and cast or wrought-iron case, often with draft tube.

TURBINE CONSTRUCTION IN GENERAL.

In general it may be said that turbines, both those on horizontal and on vertical shafts, should be self-contained; that is, all stationary parts should be securely connected to one rigid main frame or base, or to such main parts of the turbine as are arranged to serve as a frame or base,

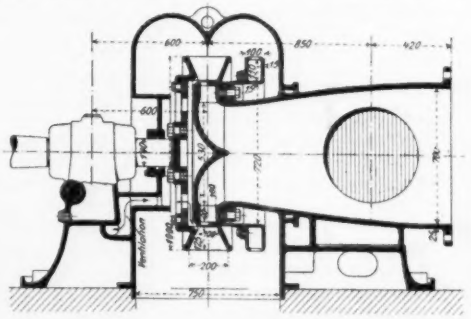


Fig. 25.

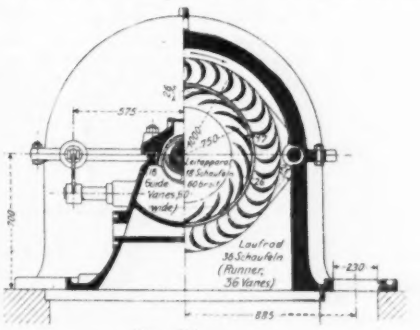


Fig. 26

FIGS. 25 TO 27.
600-HP. TURBINE OF THE ELEKTRIZITAETSWERK SCHWYZ, SWITZERLAND.
Built by Th. Bell & Co., Kriens, Switzerland.

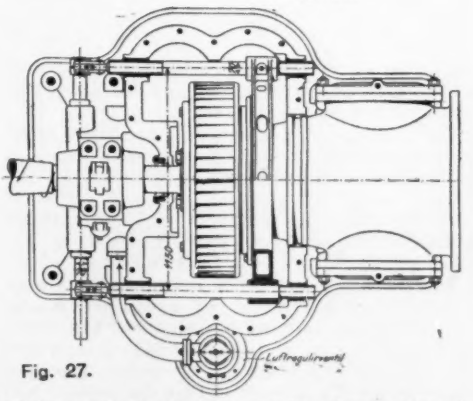


Fig. 27.

but a turbine case of iron or steel plate should never be employed as a frame.

Main frames or bases should be used in all cases, even where the turbine rests on solid masonry or concrete work, and they should be constructed of cast iron in preference to wrought iron or wrought steel, as cast iron is more rigid than the wrought metal. The shape of the frame will vary according to the general arrangement of the turbines, but a form of base-girder, with deep webs, well-stiffened sideways and with wide flanges, will answer in most cases. The joints between the frame parts themselves and between the frame and the turbines, should be planed.

Turbine frames should never be made to serve as beams, and where turbine pits or tail races are directly below the turbines, masonry arches or concrete and steel construction should be employed to bridge over these openings and to support the turbine frames.

Where turbine shafts are direct-connected to the

shaft of dynamos or other machinery, it is advisable to have the main frames of the turbines extended or separate connecting pieces provided, so that the frames of the turbines and those of the dynamos or other machinery may be bolted together rigidly, thus making the alinement and proper working of the connected machines independent of careless and faulty erection and unequal settlement.

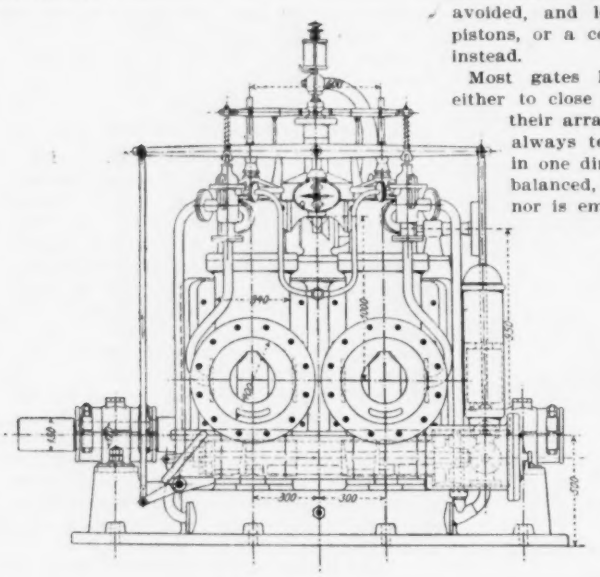


Fig. 28.

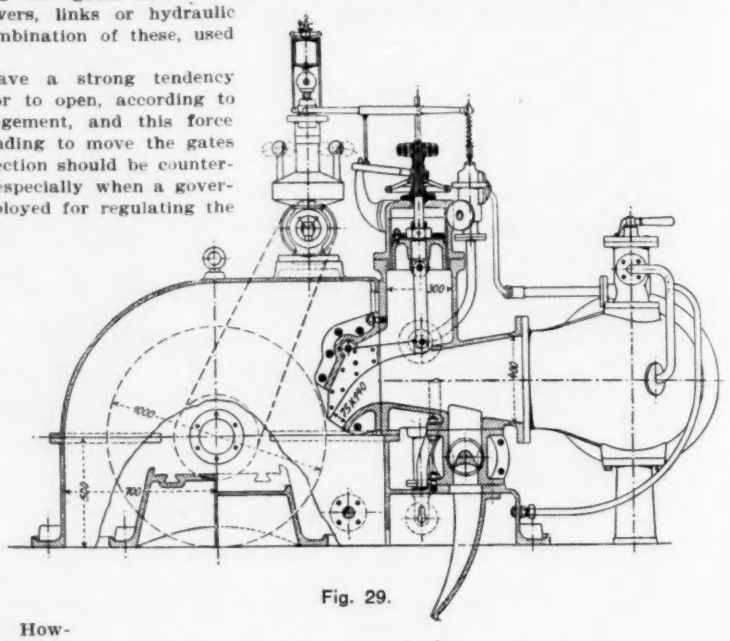


Fig. 29.

FIGS. 28 TO 30. 500-HP. IMPULSE WHEELS FOR THE ELEKTRIZITAETSWERK KUBEL, NEAR ST. GALLEN, SWITZERLAND.

Built by Escher, Wyss & Co., Zurich, Switzerland.

To transmit the power of turbines by gears should always be avoided, especially the common plan of driving a horizontal shaft from a vertical shaft turbine by bevel gears.

Turbines on vertical shafts should never be used, except where their use gives a very decided advantage over turbines on horizontal shafts. This advantage may often be gained by using dynamos with vertical shafts, direct-connected to the turbines, which gives an excellent, compact and neat arrangement, as shown by the large plants at Neuhausen, Chèvres, Rheinfelden and Beznau, all in Switzerland (see Fig. 7), and by the plant of the Niagara Falls Power Co. This arrangement was also proposed by the writer, while with Messrs. T. Pringle & Son, Montreal, for the development at Shawinigan Falls, Que., and it is to be regretted that it was not adopted, as every engineer can easily convince himself by looking at Figs. 8 to 11, here reproduced from the issue of May, 1901, of the "Canadian Engineer," where the writer's proposed plan and the plan actually carried out are published for comparison.

Centrifugal pumps with vertical shafts and piston pumps and compressors with vertical crankshafts, are also built occasionally to permit direct connection with turbines on vertical shafts, where conditions make the employment of the latter imperative. (See Figs. 1 and 2.)

The American type of runner, being a very difficult piece to mold, is now often built up from separate pieces, each piece forming one or more buckets, but such built-up runners are only permissible if they are very carefully made.

End thrust bearings with wooden steps should be abandoned and metal steps, or, better still, metal ring thrust bearings, used instead. Such metal thrust bearings should, of course, never be located in the water, but are usually placed on the end of the shaft, opposite to the end from which the power of the turbine is taken off. Both the straight and the ring bearings of the main turbine shaft should be adjustable, and should be lined with bronze as a base, and the bronze in turn lined with an anti-friction metal or babbitt, well-hammered and bored.

Cylinder gates are the simplest form of gate arrangement, but their use considerably increases the axial dimension of the whole turbine, and the distance between main bearings has to be much greater than is required with register or wicket gates.

The mechanism for actuating the gates should always be outside the turbine case or flume and connected to the gates themselves by rods, entering the case or flume through stuffing boxes. Gears for moving the gates should be avoided, and levers, links or hydraulic pistons, or a combination of these, used instead.

Most gates have a strong tendency either to close or to open, according to their arrangement, and this force always tending to move the gates in one direction should be counterbalanced, especially when a governor is employed for regulating the gate movement. However, this balancing should not be done by counterweights and chains, but by the pressure of the power water, applied to parts of the gates provided for that purpose or to balancing pistons. Besides doing away with weight, chains and their rigging, such an arrangement has the advantage that any variation in head which increases or decreases the tendency of the gate to move, also changes the balancing pressure in the same proportion. Where a long penstock is used to supply turbines having gates with a tendency to close, as is the case with nearly all gates, it is advisable to have these gates provided with dashpots, as otherwise the penstock may be wrecked, should any part of the gate rigging give way and the gates thus be permitted to close suddenly.

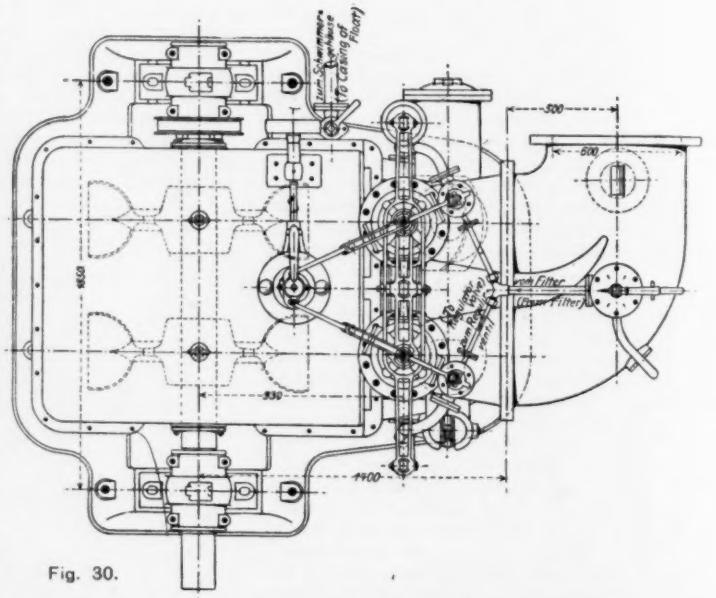


Fig. 30.

The careful design of turbines, mentioned above as necessary, includes, of course, easy access to every part and at all stages of the water.

In the following the three types of turbines suggested are considered more in detail:

TURBINES FOR LOW HEADS.

For low heads the writer considers the American turbine as the best type, and would recommend that the turbines be set above tail water and supplied with draft tubes in all cases where the head is sufficient to give enough depth of water above the turbine, so that the buckets will always be properly filled and the air prevented from being sucked through. Perhaps the best arrangement of setting is the open flume or turbine chamber, forming a direct continuation or branch of the head race or forebay, and built of masonry, concrete or concrete and steel. This plan has been adopted in a number of instances in recent years, as illustrated by the plants of the Hudson River Power Co., Mechanicsville, N. Y., the St. Lawrence Power Co., Massena, N. Y., the Montreal Light, Heat & Power Co., Montreal, Que., etc., a cross-section of their Chambly plant being shown in Fig. 12.

Where such open flumes cannot be used, the dome or case enclosing the gate arrangement should be strengthened to stand the water pressure due to the head, and a concentric or spiral cast-iron casing added to the turbine, surrounding the guide wheel and the guide wheel only, in the same manner as the casing of a centrifugal pump surrounds the fanwheel. The entrance to this casing should have an area slightly in excess of the total entrance area of all the guide buckets, which area is equal to the axial dimension of the guide bucket entrance multiplied by the outer circumference of the guide wheel. The water, while entering and inside of the casing, would thus have a speed nearly as high as when entering the guide buckets. The increased friction loss, due to the higher speed of the water in the turbine casing, will be found to be less than the losses caused by the abrupt changes in the speed and the direction of the water in the ordinary steel plate cases.

The penstock or feeder pipe, or the penstock nozzle connected to the casing, should be gradually reduced to the diameter of the entrance to the casing.

For very low heads and large powers where the casing would be of very large dimensions, or where required for other reasons, this casing might be made of steel plate, shaped as nearly

like a cast-iron casing as can be produced conveniently, and having a somewhat larger cross-sectional area than necessary for cast iron.

To have everything, even the gate domes and draft tube tees, inside a large and all-surrounding case, as is now the general practice for the sake of cheapness, is not only unnecessary, but must be regarded as an unmitigated nuisance.

Open timber flumes or timber supports for turbine settings should never be used except for temporary installations.

The regulating gates employed may be cylinder, register, or wicket gates of good design, and care should be taken to have them well balanced.

TURBINES FOR MEDIUM HEADS.

For medium heads the writer considers the radial inward flow reaction turbine in a cast-iron case as the best type, and these turbines should always be provided with draft tubes and set above the tail water.

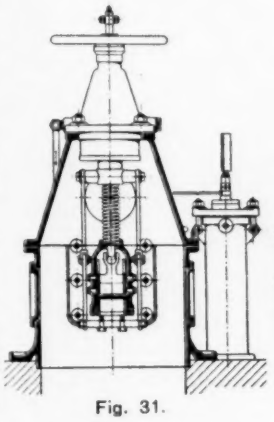


Fig. 31.

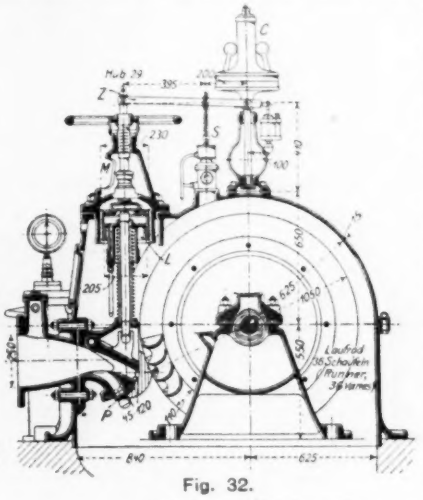


Fig. 32.

FIGS. 31 TO 33. 360-HP. IMPULSE WHEEL BUILT BY TH. BELL & CO., KRIENS, SWITZERLAND.

The cases of such turbines should resemble in outward appearance those of centrifugal pumps, and may be either concentric, like a Harmon pump case (see Figs. 13 and 14), or spiral, like the case of an ordinary centrifugal pump. (See Figs. 15 to 21.) The concentric case has the advantage that it can be used either right or left hand, while the spiral case is smaller in size, permits of a higher speed of the water flowing through it and gives a slightly better efficiency to the turbine.

The regulating gates used should be either register gates (see Figs. 13, 14, 20 and 21), or wicket gates (see Figs. 15 to 19); the latter have been

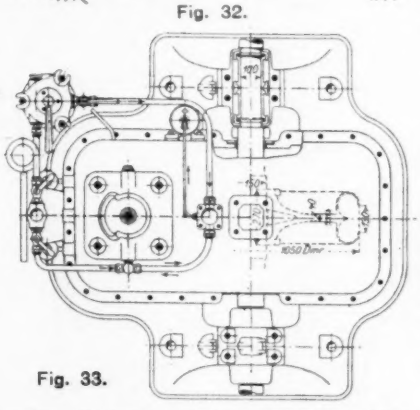


Fig. 33.

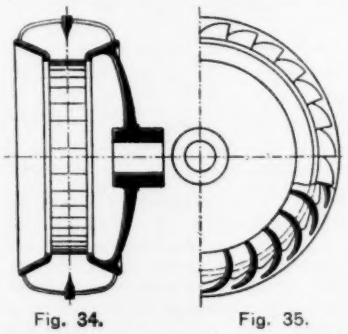


Fig. 34.

Fig. 35.

Figs. 34 and 35. Runner of a Spoon-Turbine. Built by Piccard, Pictet & Co., Geneva, Switzerland.

found to give a somewhat better efficiency for part gate opening, but are more complicated than the register gates.

These turbines are nearly always built as single turbines, and end thrust being balanced by the water pressure inside of the case, in the same manner as has been described in connection with the European practice.

As an example of the type suggested for medium heads may be mentioned the turbines at the plant of the Cataract Power Co., of Hamilton, Ont., shown in Figs. 13 and 13, to which reference has already been made in this paper, but it may be repeated here that these turbines develop each 3,000 HP. under 245 ft. head, and at a speed of 286 revolutions per minute, and give an efficiency of 80%. To this may be added that these are single turbines in concentric case and are regulated by register gates. An illustrated description of these turbines appeared in Engineering News of Nov. 14, 1901.

Another example of this type, utilizing by chance the same head as the turbines just mentioned, is the turbine shown at the Paris exhibition in 1900, and intended, with nine others, for the electrochemical works at Jajce, Bosnia. Figs. 15 to 17 show their construction. These are single turbines in spiral cases and develop each 1,000 HP. under a head of 245 ft., and at 300 revolutions per minute; they are regulated by wicket gates, and when set up in the power-house and tested under ordinary working conditions, have given an efficiency of 84%, with 0.8, or four-fifths gate opening.

Figs. 18 and 19 show a small turbine in spiral case, developing 104 HP. at 374 revolutions and 50 ft. head. Figs. 20 and 21 show another small turbine in spiral case, developing 200 HP. at 600 revolutions and 180 ft. head.

These examples of turbines here illustrated represent common practice in modern turbine building in Europe.

Another turbine of greatly different design from the preceding, on account of the axial direction of the water inlet nozzle, is shown in Fig. 22. This turbine, while having the European type of runner, was built in America, and develops 650 HP. at 210 revolutions and 90 ft. head.

It is often asserted that the close spacing of the buckets of European turbines causes trouble by choking of the buckets with bark, frazil, anchor ice, etc., but experience in Europe has shown that this is not the case, provided the racks are kept in proper repair, and turbines having only 1 in. clear space between the vanes forming the guide and runner buckets, are now running in Norway without the least trouble from bark or ice.

TURBINES FOR HIGH HEADS.

For high heads the writer considers a combination of the best points of the Pelton wheel and the radial free deviation turbine as the best type of turbine.

On page 300 of his book on "Water Power," Mr. Frizell says that the Pelton wheel "can hardly be classed as a turbine, since it cannot be placed below the level of the tail water, neither can it act in connection with a draft tube."

It is quite true that the Pelton wheel, like the ordinary free deviation turbine, cannot work when submerged, but the writer can see no reason whatever why a draft tube cannot be used in connection with it; in fact, a draft tube acts here in the same manner as when used with other free deviation turbines; that is, by increasing the velocity of the water issuing from the guide buckets, here called the nozzle, in the same way as if the amount of the draft head had been added to the pressure head above the nozzle. However, it seems that as yet draft tubes have never been applied to Pelton wheels, but this appears to be due to the ignorance of the builders of such wheels in regard to the action and the possibilities of the draft tube and the application of air admission valves.

Since the above was written the writer received "E. Reichel, Turbinenbau auf der Weltausstellung in Paris," Berlin, 1902; being a reprint from "Zeitschrift des Vereines Deutscher Ingenieure," in which an impulse wheel with draft tube is illustrated. This is shown here in Figs. 28 to 30.

The impulse or Pelton wheel, or as it may be called, the action turbine, in contrast to the reaction turbine, is nearly always enclosed in a cast or wrought-iron case. If a draft tube is to be used, the case should be of cast iron and has to be air-tight and strong enough to withstand the air pressure from outside, and stuffing boxes have to be provided for the shaft, where it projects through the sides of the case. As the wheel and the nozzle could not work properly when submerged, the water in the case or the draft tube has to be kept below and clear of the wheel and the nozzle. The vertical distance from center of nozzle, or the mean vertical distance where two or more nozzles are used, to the surface of the water in the case or draft tube is the only part of the head that is really lost, but this distance should rarely exceed 12 ins. To maintain the water level at the desired elevation an automatic air admission valve is used, as already described in this paper in connection with European free deviation turbines.

In the electric power plant at Montmorency Falls, Que., are running a number of single turbines, each developing 1,000 HP. under a head of

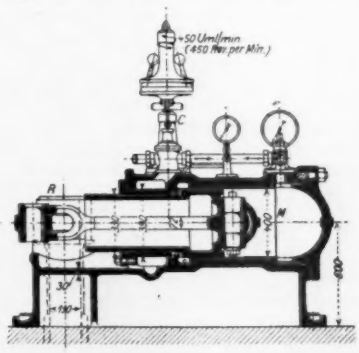


Fig. 36.

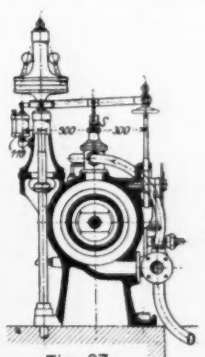


Fig. 37.

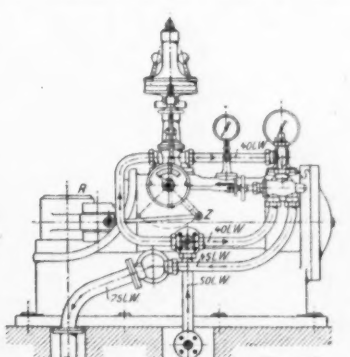


Fig. 38.

FIGS. 36 TO 38. HYDRAULIC GOVERNOR. Built by Th. Bell & Co., Kriens, Switzerland.

200 ft. and at 286 revolutions per minute, and giving an efficiency of 78.5% at nine-tenths gate. These turbines are of the European radial outward flow, free deviation type, with segmental feed, and using a draft tube, and therefore are supplied with such air admission valves, and many engineers may have observed them when visiting that plant. Their principle is very sim-

pie. (See Figs. 23 and 24.) A vertical pipe of about 12 ins. diameter is placed alongside the turbine, with its top end connected to the turbine case and its bottom end to the draft tube, in the same manner as a water gage on a boiler. In this pipe is a copper float and when the water level in the turbine case rises this float rises also and opens an air admission valve on top of the turbine case, the water level and float at once drop and the valve closes again. When the turbine is running under a steady load, the valve usually comes to rest in a position where it supplies air at the same rate as it is absorbed and carried off by the water. A gage glass or water gage should be attached to the turbine case or float chamber, so it can always be seen whether the air valve is maintaining the water at the desired level.

Figs. 23 and 24 show the turbines at Ouiatchouan, Que., being identical with those at Montmorency Falls, but of later design. These turbines develop 1,000 HP. each, at 225 revolutions and 240 ft. head. Figs. 25 to 27 show another free deviation turbine provided with draft tube and developing 600 HP. at 400 revolutions and 246 ft. head. In Figs. 28 to 30 are shown a pair of Pelton wheels in cast-iron case and provided with draft tube, and by-pass regulation with baffle plates. Here the float chamber is not directly attached to the case. Each pair of these wheels develops 500 HP. at 375 revolutions and 295 ft. head. The variation of the water level in the draft tubes of these wheels is less than 2 ins.

With the head of 1,000 ft. and 400 revolutions per minute, an action turbine or Pelton wheel would have to be 6 ft. in diameter and an air-tight case could easily be provided for it. With slower speeds or higher heads requiring larger wheels an air-tight case would be rather expensive, and as the percentage of gain due to the use of a draft tube is only trifling with heads of over 1,000 ft., draft tubes will hardly be used for wheels larger than 6 ft. in diameter.

The regulation of Pelton wheels is at present accomplished by throttling the water by an ordinary gate valve before the water reaches the nozzle part, which is a very poor arrangement, or by having a cone piece inside the nozzle, which, by being pushed more or less into the exit opening of the nozzle, reduces the area of that opening to the size required.

For very high heads or very long penstocks where a sudden reduction of the size of the nozzle opening would cause dangerous strains in the feeder pipe, the by-pass regulation is employed, the usual arrangement being to have the nozzle connected to the feeder pipe by a flexible joint and to deflect the nozzle more or less away from the buckets, in proportion to the reduction of the load on the wheel.

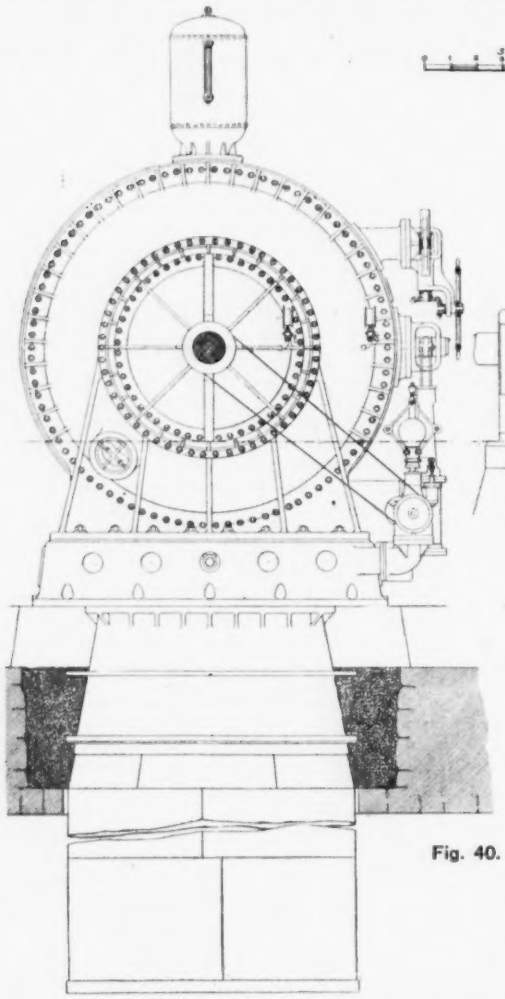


Fig. 40.

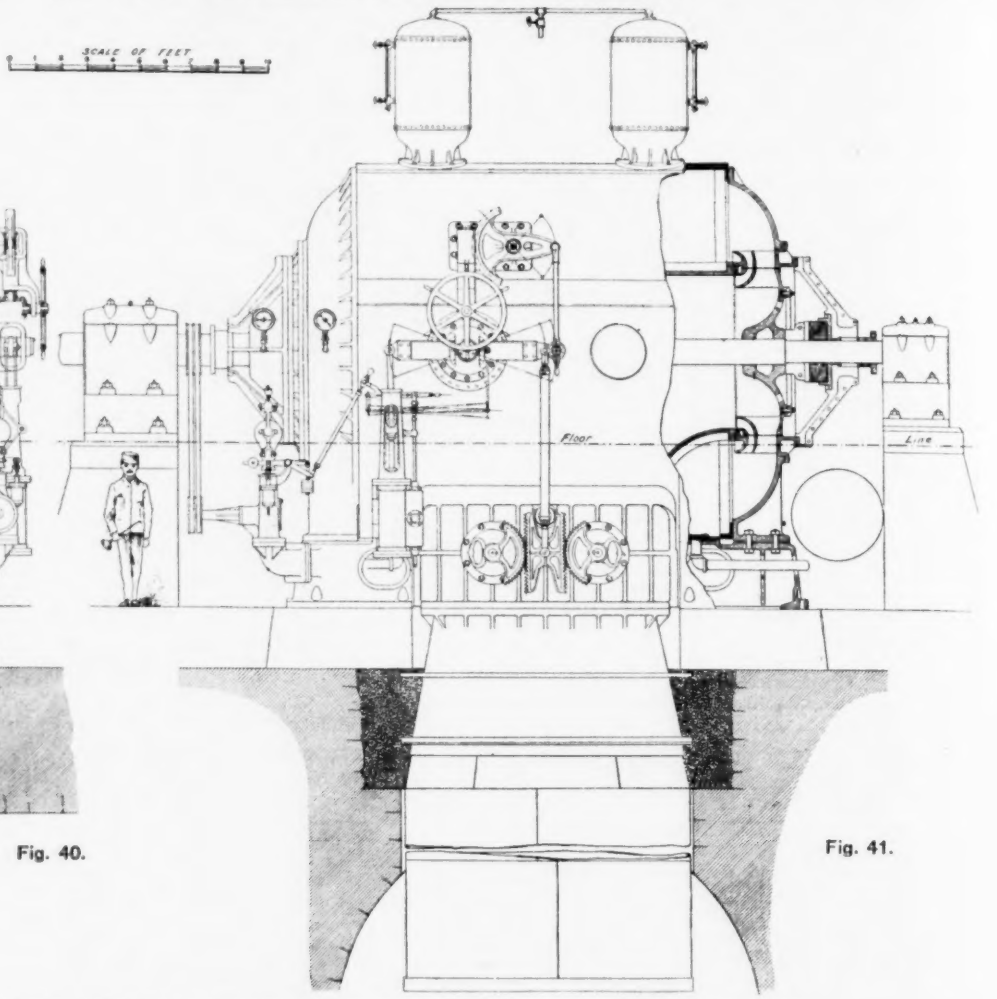


Fig. 41.

FIGS. 40 AND 41. 6,000-HP. TURBINE FOR THE SHAWINIGAN WATER & POWER CO., SHAWINIGAN FALLS, QUE.
Built by the I. P. Morris Co., Philadelphia, Pa.

Height of fall, 125 ft.; rev. per min., 180; diam. of runner, 6¼ ins.; diam. of supply, 11 ft.; cu. ft. of water per sec., 576; 32 vanes in turbine runner; 36 vanes in guide ring.

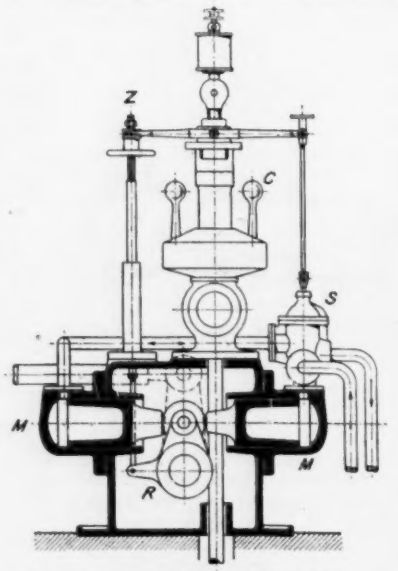


FIG. 39. HYDRAULIC GOVERNOR.
Built by Escher, Wyss & Co., Zurich, Switzerland.

For regulation by changing the amount of water supplied to the wheel, hardly anything better and simpler can be found for small nozzles with circular cross-section, than the movable cone inside the nozzle, but for large nozzles the writer would recommend a rectangular cross-section and a sliding wedge inside of the nozzle, this wedge to be of the same width as the nozzle opening, and to slide against one of the nozzle walls. The increased friction loss due to the rectangular shape of the nozzle is so slight in comparison with the high heads used with Pelton wheels that it need not be considered.

For by-pass regulation the flexible pipe joint used in connection with high water pressures is always a source of much trouble, and should be abandoned. The writer would recommend instead the employment of a double nozzle, having one jet directed against the buckets and the other jet clear of the buckets. These nozzles should be of rectangular cross-section, and each should have one of its sides hinged, so that the nozzles would work like the beak of a bird. The loose sides of the two nozzles should be so connected that one nozzle is always open when the other is closed and the sum of both nozzle openings is always equal to one full opening.

Figs. 31 to 33 show an impulse wheel provided with such a double nozzle, but here the by-pass nozzle is closed or opened by a slide. This impulse wheel develops 360 HP. at 500 revolutions under 492 ft. head.

When draft tubes are used the by-pass discharge, striking the water surface, might throw

the latter into such commotion as to interfere with the proper working of the wheel. In this case baffle plates should be used, as shown in Figs. 28 to 30, or spouts, so arranged as to carry the by-pass water below the surface of the water in the case or draft tube.

The rectangular nozzles, both for gate and by-pass regulation, resemble in shape the turbine guide buckets, and shape and size of nozzles and wheel buckets have to be carefully adapted to each other. Rectangular nozzles having clear exit openings as large as 6 × 3 ins., have been used in Europe.

The free deviation turbine and the impulse or Pelton wheel are approaching each other more and more in European practice, and will soon be fused into one single type, retaining as far as possible the best features of both. A design standing between the present free deviation turbine and the impulse wheel is the spoon turbine, a runner of which is shown in Figs. 34 and 35.

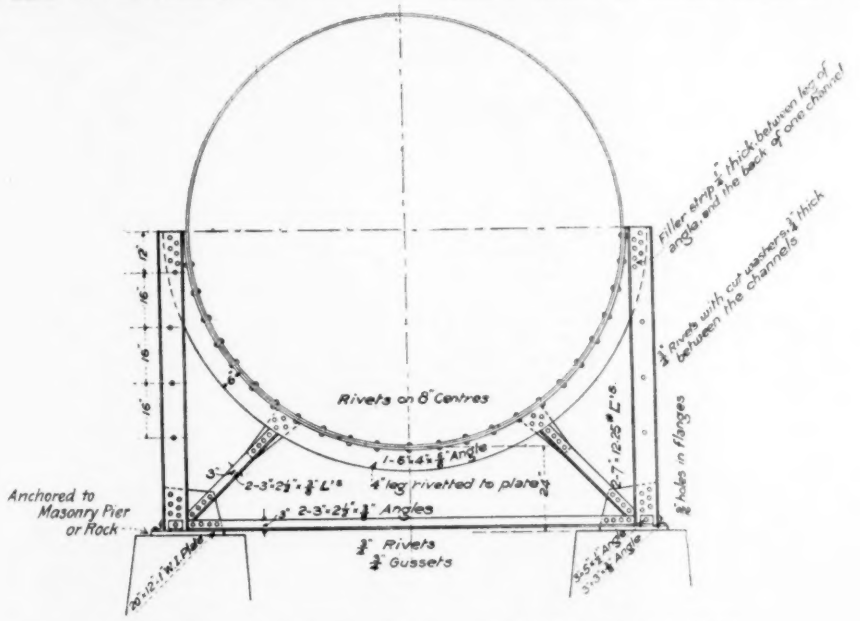

Filler strip ⅜" thick between leg of angle and the back of one channel
¾" Rivets with cut washers ⅜" thick between the channels
Rivets on 8" Centres
1-6"x4"x⅞" Angle
4" leg rivetted to plate
2-3"x2½"x½" L's
2-3"x2½"x½" Angles
¾" Rivets
¾" Gussets
Anchored to Masonry Pier or Rock
¾" holes in flanges
3-5"x3½"x⅝" Angle
3-5"x3½"x⅝" Angle

FIG. 42. STEEL PIER FOR PENSTOCK OF 9 FEET DIAMETER.

RECENT PRACTICE IN MACHINE TOOLS.*

By Jas. K. Cullen.†

Although there are records of lathes in the early part of the 16th century, the antiquity of machine tools is not great, but the information we have relative to their origin is extremely limited. Little more than a hundred years ago there were in existence only a few rude specimens of machine construction, among the number being tilt hammers, mills (so-called) for boring cannon, and engines (as they were then known) for cutting the teeth of clock-wheels.

As the efficiency of any machine is determined by the quality and quantity of its output, modified to an extent by the skill of the workman, and the cost of operation, the designer must be familiar with the details of the various lines of manufacture in which it may be employed. He must also possess a theoretical knowledge of the properties of materials, coupled with a very broad practical experience. His labor is somewhat lightened on account of the comparatively limited number of methods employed in removing surplus from, or changing the form of, materials of different kinds. Rolling, forging, pressing, planing, turning, milling, grinding, drilling, tapping, punching, shearing and sawing, cover the most important; and all machines for effecting these operations can virtually be classified under one or the other heading.

The most noticeable feature in recent years in machine design is the immense increase in strength and power, and the introduction of cutting steels having lasting properties under excessive speeds and feeds that appear phenomenal, will make it still more pronounced. From 50 to 100% increase in power with proportionate additional strength is now not unusual to provide for cutting speeds of 40 to 75 ft., and the limit is not yet in sight.

The very first tool specially designed and built to meet the new conditions was a driving-wheel lathe furnished the Altoona shops of the Pennsylvania R. R. Its swing was sufficient to turn tires 52-in. to 68-in. on the tread at speeds ranging from 10 ft. to 30 ft. per minute. It is driven by a 25 HP. variable speed motor, connected to the gear train by a magnetic clutch. The clutch is so constructed that the current can be passed from the end giving the speeds mentioned to the opposite end, where a reduction to 4 ins. is obtained, this being used to cut out hard spots. The changes are instantaneous and made by the operator simply throwing a switch. A 3 HP. motor is attached to the end of the bed for adjusting the right-hand headstock. The gears are all cut and are of gun iron and steel. The main spindle bearings, 13 ins. diameter, 16 ins. long, are of high grade bronze, and the internal sliding spindles, of steel forgings, 0.45% carbon, 7 ins. in diameter. The power and strength are sufficient to give a pressure of 18,000 lbs. at each tool, which is as much as the steel will stand. The carriages and tool rests are of the most substantial construction and capable of resisting the enormous strains that are imposed upon them. The weight, 80,000 lbs. (about double that of the ordinary lathe of the same swing), indicates its massiveness and rigidity. I have no record of its output, but as each rest is carrying two cutting tools it may reasonably be presumed that the time of turning is materially reduced.

Another perhaps equally important change is the adoption of motor drive. This was received at first with some degree of doubt, but it has come to stay, and its value is no longer questioned. While there are instances in which the application of motors has been carried to extremes, their use in connection with the larger and most of the medium size tools has proved eminently satisfactory. The extremes referred to are found where the attachment has been made to very small tools, the cost, size and weight of the motors offsetting the economy in their use. The experience of those who have most carefully investigated the subject has demonstrated that direct connection is only serviceable on the larger machines, and that the smallest should be grouped and operated by short lengths of line shaft with motor attached. It is expected that in time the cost and design of the smaller motors may be modified so as to extend the range of their usefulness, but at present the limit is plainly visible.

The greatest difficulty encountered by the manufacturer is the diversity of opinion among the purchasers regarding the type of motors that should be employed. Between alternating current, series, compound, shunt wound and multiple voltage systems, his lot in life has become a most unhappy one. No standard construction suitable for all can be maintained, consequently specials must be built at increased cost and delay in delivery. If alternating current, variable-speed motors can be produced of anything like uniform dimensions for the same power, most of the annoyance now occasioned will disappear. The advantages accruing from this method, under correct conditions, are well understood, the more prominent being speed regulation, absence of belts, free head room for crane service, and economy in operation.

The magnetic clutch on machines with reciprocating movement promises to meet the requirements fully, although as yet it has not reached the perfect stage. Residual magnetism is the troublesome quantity, but there is every prospect of this defect being eliminated. Magnet relief for planer, slotter and shaper aprons has just been introduced, and has accomplished what no former mechanical contrivance could be made to do.

For convenience we may divide all machines into two classes, general and special. The former includes those employed in doing the work on a great variety of pieces, and the latter for some specific duty only, or, at the most, for a very limited number of parts.

SPECIAL TOOLS.

The trend toward the specials is particularly noticeable in railway machinery, the axle lathe, car-wheel borer, cylinder borer, frog and switch planer, the rod borer, the car-wheel lathe, the frame planer, the frame slotter and numerous others.

Sharp competition, making minimum cost with maximum output of product a necessity, created the call for such tools, and their use has fully demonstrated their efficiency. One great advantage they possess lies in the requirement of unskilled labor in their operation. Any man entirely lacking in mechanical experience can soon be taught to manipulate them so skillfully as to obtain the best results.

An objection that has been urged against them is the insufficiency of work of a kind suitable to keep them continually employed, but this is usually not well founded. As a general proposition, any machine costing not over $3,000 (and few of them for railway purposes are as expensive as this) can remain idle at least 50% of the time without loss to the company. Interest on the investment at 6% per annum is $180; wear and tear, at 10% for six months, is $150; labor, at 25 cts. per hour for six months, is $375; general expense, at 15 cts. per hour, is $225; a total of $930. Estimating the value of the product, exclusive of material, at 65 cts. per hour (a very low figure), gives $975, showing a slight balance for the profit side of the ledger. The most tangible economy, however, is in the shortening of the period in which locomotives and cars are out of service.

The ancient practice of boring cylinders in lathes, with boring-heads filled with wooden blocks, days being consumed in the work, has given way to simpler methods in cylinder borers, the main opening and the end facing being accomplished simultaneously, with a saving of time of nearly 50%. The latest double axle lathes have increased the output from 4 or 5 axles per day to 15 or 20. Driving wheels are now finished at the rate of two pair per day, instead of one pair in two days. Car wheels are now bored in from 7 to 10 minutes, two cuts being taken; and steel-tired wheels are turned in car-wheel lathes in two hours per pair.

Frames, in frame slotters, planers and drills, are completed in 20% of the time formerly required; and in arch-bars, tie-bars, side sheets, crown sheets, flue sheets, and a large variety of boiler and car work, eight to ten holes can now be drilled in the time heretofore needed for one, with arch-bar and multiple drills. Power presses, with pressure gage and safety attachments, turn out four to five times the work the older machines could, and do it so well that trouble from broken and loose wheels is now rarely encountered.

Bending rolls shape up boiler shells of the heaviest material, at one pass, at a speed of from 10 to 12 ft. per minute. Hydraulic riveters and flangers, punches with spacing tables, shearing and plate planing tools have worked a miracle in boiler work. Three-spindle bolt cutters and seven-spindle tappers have supplanted the single and double-spindle tools, and automatic screw machines now turn out more bolts in an hour than a lathe could in a day.

Tools and appliances more especially adapted for repair work include portable cylinder borers, valve-seat planers, crank-pin turners, flue welders and cleaners, stay-bolt cutters, portable crank-pin presses, and numerous devices of similar character. The work done by them has effected an enormous saving in proportion to their cost.

Air compressors, making the service of pneumatic hoists, chisels, drills, flue expanders, cushion cleaners and paint sprayers possible, are now very generally installed with excellent results, and bulldozers, upsetting machines and steam hammers are indispensable adjuncts of the modern smith shops.

GENERAL TOOLS.

While so much thought was being expended on the special, the general class has not been neglected. Boring, planing, shaping, slotting, turning, drilling and other machines have been virtually redesigned, supplied with automatic stops wherever possible, and quick adjustments, by hand and power, have replaced older and slower movements. The range of feeds and speeds has been enlarged until, with the additional power supplied, the only limit is the durability and strength of the cutter.

Convenience in manipulation and minimizing cost of repairs are points that have obtained more than casual investigation. The reduction of frictional losses, a subject overlooked by the copyist, has been diligently studied by the expert designer with the most gratifying returns for his efforts. Correct shape of gear teeth, momentum of pieces running at high velocities, torsional, longitudinal and transverse strains have each been investigated by careful and extended experiment and the information received used to the betterment of previous designs.

WOOD-WORKING TOOLS.

Wood-working machinery has kept pace with the iron-working, and this line embraces machines very different from those of even ten years ago. Old patterns have been greatly improved and new ones added. By keeping

*Abstract of a paper presented at the November meeting of the Western Railway Club, Chicago.
†President Niles Tool Works, Hamilton, O.

the automatic feature constantly in mind, mistakes due to carelessness can scarcely occur, the acts of cutting, handling, starting, spacing and alining being performed almost independently of the operator.

The increased carrying capacity of cars increased the dimensions of the material composing them, and therefore the need of larger and heavier machines for handling the different pieces was imperative. Among the most noteworthy is the four-sided car-sill planer and timber dresser, capable of planing the several sides of the largest timber in one operation. The hollow-chisel mortiser has crowded to obscurity the old stroke mortiser, doing the work in one-fifth the time without noise or vibration. Its companion is the tenoning machine, made either vertical or horizontal, with which tenons can be cut on both ends without reversing the timber.

The traversing gainer has developed from the simple hand to the accurate and positive automatic machine, with traveling carriage, adjustable head and stop attachment for correctly gaging the depth of cut. A combined gainer and tenoner is now being perfected that promises to still further reduce the cost of this class of work. Boring machines, with three or more spindles, producing holes at any angle, enable one man to do the work of three on any other. Band saws, cross-cut, cut-off and rip saws have also received their share of attention.

The universal wood worker is not so well known in car shops, but is enlarging its field steadily. For doing a variety of work quickly and perfectly it is unexcelled. Planing, sawing, gaining, tenoning, rabbeting, boring and shaping are all under its scope, and this, with its simplicity, should make it indispensable in repair shops. The molding machine has possibly been more improved than any other. As it is designed for fine work, everything depends on its accuracy. It was evolved from a crude planer, with a single head, and now the second, third, fourth and even fifth head has been added, with corresponding increase in its capacity.

MACHINERY FOR HANDLING MATERIAL.

While this paper can only touch the surface of the subject, it would be still more superficial if it failed to refer to the marked advance in handling material and completed constructions. Electric overhead, traveling cranes, with auxiliary hoists, have signalled the disappearance of drop-tables, and the era of main strength and awkwardness is at an end. Motor drive for transfer and turntables has solved the problem of locomotive and car manipulation.

We might continue enumerating machines and appliances of similar character, but it seems unnecessary. Those mentioned will show sufficiently the general trend, and the effect of their use is manifest in the enormous increase in business and profits obtained by those roads on which economic problems have been solved.

A FREEZING PROCESS FOR BUILDING THE RIVER TUNNELS OF THE PENNSYLVANIA R. R. AT NEW YORK.

About a year ago the Pennsylvania R. R. Co. made the interesting announcement that it proposed to build a tunnel from its lines on the New Jersey shore under the Hudson River, Manhattan Island, and the East River, to a connection with the lines of the Long Island R. R., on Long Island. The plan as announced provided for two parallel single-track tunnels between the termini mentioned and for a supplementary pair of tunnels for local trains between the Long Island R. R. lines and a central station on the line of the main tunnel in New York city. In crossing the Hudson River the main tunnels will have to be built through soft silt, which experience has shown to be one of the most treacherous materials ever encountered by the tunnel builder, and in passing under the East River all four tunnels will have to pass from earth into rock and from rock into earth at two or more points. The difficulties certain to be met in penetrating materials of this nature are obvious, and were fully recognized by the managers of the Pennsylvania R. R., who appointed early in 1902 a commission of prominent engineers to consider plans and provide ways and means for solving the problem.

One of the plans considered by this commission was that of Mr. Charles M. Jacobs, M. Inst. C. E., the engineer in charge of the work. In general, Mr. Jacobs' plan was to drive each tunnel with a shield in the usual manner and line it with cast iron. Then traps were to be opened in the bottom of the lining at intervals of about 150 ft., and through them cylinder piers sunk to bed rock. Next parallel trusses were to be erected inside the lining and firmly attached to it, with their ends resting on these piers. By this construction the weight and jar of trusses will not be carried by the lining and transmitted to the earth in which it lies, but the trusses will carry all the loads and transmit them to the piers.

More recently a plan has been submitted to the commission by Mr. Charles Sooysmith, M. Am. Soc. C. E., for employing the freezing process, which has frequently been used in the past for shaft sinking, to build the subaqueous portions of the tunnel. In general Mr. Sooysmith's plan is to drive from the river surface above, a pile foundation for the whole length of the river tunnel, and then to build the tunnel structure just above this foundation by freezing the surrounding silt and then excavating through the frozen material. The plan is an ambitious one, and it has been worked out in considerable detail by Mr. Sooysmith, who has given us the following account of the methods and apparatus to be used:

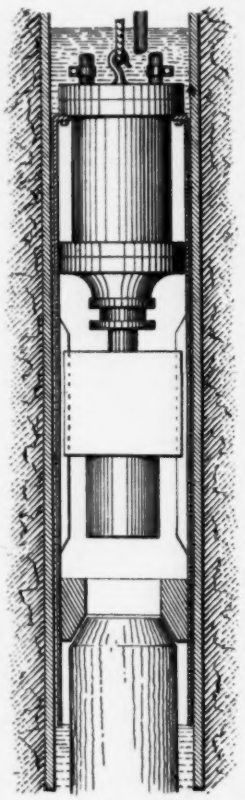


Fig. 1. Sectional Elevation of Apparatus for Subaqueous Pile Driving.
Charles Sooysmith, M. Am. Soc. C. E., New York city, Inventor.

To engineers the question of prime importance has been that of the stability of a tunnel located in the silt composing the bed of the Hudson River.

In designing the tunnel structure, unless material is added to this to give it weight, it would be generally lighter than the silt it displaces, and hence it would have a tendency to rise rather than to settle. This fact would seem to make any provision for a foundation for the tunnel structure unnecessary, were it not that the factor of real importance to be provided for is the varying weight and load from the traffic and the effect on the silt of the vibration caused by the moving trains. Nothing is better understood in engineering than the fact that material which will support indefinitely a quiescent heavy load without settlement may give way rapidly when the influence of a comparatively slight pounding is introduced. What is needed is transmission of the vibration of moving trains to such a larger mass of the underlying silt that the vibrations or shocks will be dissipated and absorbed.

Thus it is undoubtedly wise that the plans of the Pennsylvania R. R. Co., as indicated by what has been published about them, contemplate some sort of a rigid foundation for the tunnel. Unquestionably a continuous bearing of piles would be the ideal foundation. The pile piers along the river front show how readily piles can be driven and how great and permanent their bearing capacity is.

A very simple and practicable way of providing this pile foundation is outlined: A barge would be equipped with the usual leads and with powerful pumps as for the common process of sinking piles by aid of the water jet. A steel tube large enough to contain or receive the pile would be jetted down in the same manner as a pile, until its lower end reaches about the level at which the bottom of the tunnel would be. The pile is then telescoped through the tube, being driven by a follower or by means of a Nasmyth hammer lowered down into the tube. This would be worked by compressed air. In order that the working of the hammer may not be interfered with by the water, the hammer is encased in a shell, which extends to below the top of the pile, and by keeping air in this shell, the water is excluded from the space in which the hammer works. After the pile has been driven till its top is at the desired level of bottom of tunnel, the tube is withdrawn. The hole above the pile may, if desired, be filled and the filling tamped after partially or entirely withdrawing the tube. The leads and tubes should be multiple and adjustable, so that each pile would be located before the tube for the previous one is withdrawn. By cutting the piles to such length as will give the desired resistance when driven and with the perfect control permitted by use of the Nasmyth hammer, the piles can be driven so that they would be at the exact level desired.

The method suggested for the construction of the tunnel itself is an application of the well-known freezing process, by which many deep and difficult excavations have been made for shafts in Europe and at least one in this country—a shaft at the Chapin Iron Mine at Iron Mountain, Mich., where a cylinder of water-bearing strata 9 ft. in diameter, and extending 100 ft. below water level, was first frozen and the shaft then excavated through the material thus solidified. This work was done very quickly and successfully, and at the time engineers expected it would be followed by a very considerable use of the process. It has, indeed, been frequently used in Europe, but there have been few places in the United States where the difficulties and expense of sinking a single shaft justified the outlay for installing a refrigeration plant.

For shaft work, it is usual to sink vertical pipes arranged in a circle around the site of the shaft. These pipes are closed at the bottom and each contains a smaller pipe open at the bottom. Brine, cooled by an ice machine, is circulated through these pipes until a frozen wall is made, shutting off water and sand, and permitting the excavation and shaft work to be readily done within the protection of this frozen cofferdam.

To apply the freezing process to the construction of subaqueous tunnels, there has seemed the almost unsurmountable difficulty of reaching the earth to be frozen by a circulating medium with which to accomplish the freezing, and it is to provide a way to attain this end that the present designs have been made.

In constructing subaqueous tunnels by compressed air, the difficulties and large cost occur chiefly because of the difference of hydrostatic head at the top and bottom of the heading and from the size of the shield. When this difference is small, as in a tunnel but 6 or 7 ft. in diameter, the tunnel can be excavated through the most difficult materials with comparatively small expense. The plan contemplates therefore, that a small pilot tunnel 6 or 7 ft. in diameter be built on the center line of the proposed main tunnel, and that this be used as a refrigeration chamber, from which to freeze the material surrounding this small tunnel. This may be accomplished by maintaining a temperature below 0° F. in this pilot tunnel, just as is now done in cold storage plants where, in some cases, brine is circulated through pipes located in the cold chambers and in some instances air cooled in another room is blown in and circulated. The pilot tunnel may be temporarily lined with metal plates and brine may be circulated through pipes laid against this, leaving the center unobstructed, so that the freezing may follow closely the excavation of the pilot tunnel; or, when the pilot is first completed its lining may be made tight and the brine circulated through the body of the small tunnel itself. When it is desired to extend the pilot while freezing is in progress from it, the walls will be made annular so that access can be had through the center.

Where a double-track tunnel is to be constructed requiring a very large excavation, radial pipes may be pushed out in sections at intervals from the pilot tunnel and the brine circulated through these. In the work done at Iron Mountain the material was frozen to a distance of 9 ft. in 72 days from pipes 8 ins. in diameter, with brine at zero temperature. Thus the material may be solidified to a sufficient distance to enable the full-sized tunnel to be excavated at one time, still leaving an ample protection of frozen material outside of the excavation.

Another plan of procedure not necessitating the use of radial pipes would be to begin excavation when the freezing had extended 4 or 5 ft. from the pilot tunnel, and enlarge the excavation a foot or two at a time by successive operations as the freezing proceeds outwardly, doing the freezing by a circulation of cold air.

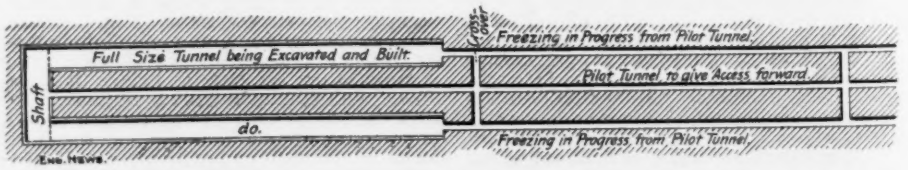

Full Size Tunnel being Excavated and Built.
Shaft
do.
Freezing in Progress from Pilot Tunnel.
Pilot Tunnel to give Access forward.
Freezing in Progress from Pilot Tunnel.
Eng. News.

FIG. 2. DIAGRAM ILLUSTRATING METHOD OF DRIVING SUBAQUEOUS TUNNELS BY THE FREEZING PROCESS.

Large refrigeration plants are now in use in New York and other cities in which the refrigeration service is carried several blocks from the producing plant.

By the methods outlined above a cylinder of the

material in the bed of the river can be readily solidified, and at a relatively small cost, accurately ascertainable beforehand. From the records of the work done at Iron Mountain, and tests made on silt dredged from the bottom of the Hudson, the speed at which the freezing can be done, the number of thermal units required to freeze a given amount and the loss by cooling outside the mass frozen are known. Tests made on the frozen silt show its strength to be equal to that of good concrete. Hence, while the material would be solidified to a distance of several feet outside the space to be excavated, the strength is such that 2 or 3 ft. of frozen wall would suffice to prevent collapse.

In excavating for the tunnel, the methods now common in the mining of frozen material in the Klondike could be employed. Also some of the appliances used in the mining of coal would be well adapted.

Pilot tunnels can be built under the Hudson at about the rate and cost of those that have been run out under Lake Michigan and Lake Erie at many points for water-works intakes. These have been built in many instances from 10 to 15 ft. per day and at a cost of less than $20 per ft. As bearing on the possible cost of freezing the silt, which does not contain 40% in volume of water, it may be stated that plants in operation in New York city are producing ice at an actual cost of less than $1 per cu. yd. As bearing on the probable cost of excavating the frozen material, it may be stated that the cost of mining coal and bringing it to the surface is generally less than $1 per cu. yd.

In answer to the question whether the material will not thaw quickly after the excavation is made, it may be observed that the temperature of the frozen mass will be considerably lower than the freezing point and that the surrounding earth will conduct heat but slowly. The loss of cold toward the interior excavation will also be slow, as the air will be changed only as required for ventilation. Thus there will be ample time for constructing the permanent work, which could, however, follow close to the finished excavation.

With reference to the feasibility of building the tunnel structure of masonry against the frozen earth, it may be said that freezing does not seriously, if at all, injure Portland cement, and it will be practicable to keep the temperature of the masonry above the freezing point for a sufficient time to permit the cement to set, and at the same time maintain the frozen wall outside. It is a fact that in the shafts sunk by the freezing process, but little trouble from thawing, or in building the lining, has been experienced, and the frozen wall about the excavation has been known to remain frozen for months after the completion of the work.

The programme suggested thus contemplates, first, providing a continuous foundation of piles, then excavating over these a small tunnel, which is first utilized as a refrigeration chamber to solidify the entire mass over the piles, and this tunnel is then enlarged to an excavation in which the structure of the full-sized tunnel is built upon the piles.

The plan outlined obviates the disadvantages of costly work in compressed air in the main tunnel heading and the hazard to life from the effects of compressed air. It converts the material about the space to be excavated into a rock-like mass, which will almost wholly eliminate the liability to accident, so imminent in compressed air work, from collapses or inflow of water, with its probability of great loss and long delay in the completion of the work.

The use of the pneumatic shield calls for a heavy and costly structure of cast iron—which material, when it can possibly be avoided, is no longer used in good practice where it is subject to danger of cracking from the vibration of moving trains—a result which would be a most serious matter in a subaqueous tunnel.

The freezing method permits the excavation of a chamber, in which, open to inspection at all times, a much better and cheaper tunnel wall may be built consisting of a steel shell inbedded in concrete, or any desired material and design may be used. This can be built in exact grade and alinement, a matter of much difficulty with a shield. By the freezing method the tunnel can be located closer to the bed of the river, thus reducing the grade.

While the freezing method has not yet been applied to horizontal excavations, it has been largely used for vertical shafts, and its application to a tunnel requires nothing not already absolutely proven in actual works. The refrigerating can be done just as is being done in cold storage warehouse plants in all of our large cities. The rate of freezing, the amount of refrigeration required, the strength of frozen earth and the cost of excavating it have been ascertained by work already done, and in addition to the advantages over the pneumatic method of safety and certainty, decided advantages in economy and speed are shown.

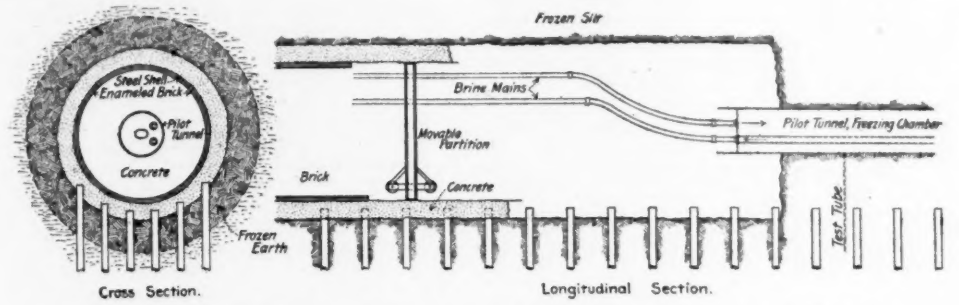


FIG. 3. DIAGRAM SHOWING ARRANGEMENT OF FREEZING PILOT AND METHOD OF CONSTRUCTING THE TUNNEL TO THE RUN OF IT.

The projected tunnels under the East River, including that of the Rapid Transit Railway, as well as those of the Pennsylvania and Long Island railways, will pass through a more difficult material even than the silt of the Hudson River, although it will be so solid as not to necessitate an artificial foundation. The formation here consists of strata of mud, gravel, sand, quicksand and disintegrated rock, and owing to its permeability it will be difficult to maintain air pressure in a shield. It would, however, be comparatively easy to construct a heading small in diameter such as would suffice for a freezing chamber. If the rock portion of the work is fissured it may be frozen in a short time by reason of the small amount of contained water.

In further explanation of Mr. Sooysmith's proposed plan of operations, we give the accompanying illustrations made from patent drawings and sketches furnished to us by him. Fig. 1 is a sectional elevation showing the proposed pile-driving apparatus for sinking the foundation piles. In this drawing A is the tube which is jetted down into the silt, as described, and into which the pile B is telescoped; C shows the diving bell arrangement, which encloses the head of the pile and within which is the Nasmyth hammer for driving the pile. By means of this apparatus the pile-driving can be carried on below water level and yet the hammer blows be delivered in air as freely as would be the case in operating in the open air. Fig. 2 is a diagram showing a possible sequence of operations in constructing the tunnels. As will be seen, three parallel pilot tunnels are first driven; two of these are on the center lines of the proposed tunnel, and the third is midway between these two. The two outside pilots are used for freezing and the middle pilot serves to give access to the work forward. As soon as the freezing has been completed, from the outside pilots the full tunnel section is excavated and lined at the rear of each. Fig. 3 is a diagram showing the freezing pilot and the tunnel work behind in more detail, and is self-explanatory.

COST OF COPPER MINING IN THE LAKE SUPERIOR DISTRICT.

"Mineral Resources of the United States" for 1901, compiled under the direction of the United States Geological Survey, contains the following interesting data relative to production and cost of production of copper. In 1901, the total output of copper mines in the United States was 268,782 long tons, of which the Lake Superior District produced 25.6%; Montana, 38.2%; and Arizona, 21.2%. This was some 2,000 tons less than the high water mark of the preceding year, but still more than double the output of 1891, and more than eight times the output of 1881.

The price of ingot copper in 1901 held with very little fluctuation close to 17 cts. per lb. until December, when prices suddenly crumbled, falling as low as 12⅞ cts., which, however, was still higher by ¾-ct. than the best price of 1898. It will be remembered that in January, 1899, copper suddenly jumped from 13 cts. up to 17 cts., later reaching 19½ cts. in April.

A table in "Mineral Resources" shows the highest and lowest market prices for every year since 1860, the highest price being 55 cts. in 1864, the lowest being 9 cts. in 1894.

The Quincy Mine stamp mill in 1901 crushed 886,266 tons of rock, yielding nearly 23.2 lbs. refined copper per ton. In the mine there were employed on an average 533 miners at $62 per month, according to a wage contract. The running expenses at the mine were $1.61 per ton of ore milled, to which must be added $0.23 for the smelting, transportation, etc., and $0.07 for taxes, making a total of $1.91 per ton. The actual labor cost of mining was $0.44 per ton, assuming that the miners were employed 12 months at the wages above given, and that all men actually engaged underground are included in the 533 "miners." The Atlantic Mining Co. (Lake Superior also) stamped 409,124 tons of rock in 1901, which yielded 0.57%, or 11.4 lbs. copper per ton, which was sold at 15¾ cts. The records of cost at this mine for a long series of years have appeared in previous volumes of "Mineral Resources," but the following tabulation may be of value:

Items of cost per ton of rock treated.	1898.	1900.	1901.
Mining*	$0.764	$1.036	$1.105
Transportation to mill	0.050	0.069	0.076
Stamping and separating	0.249	0.247	0.220
Freight†	0.174	0.147	0.154
Total working expenses	$1.237	$1.499	$1.555
Tot'l expend. incl. const'n.	$1.36	$1.78	$2.02

*Selecting, breaking and all surface expenses, including taxes. †Smelting, marketing and New York expenses.

In the year 1891, the cost of milling at the Atlantic Mine is given in greater detail in the Transactions of the American Institute of Mining Engineers, Vol. 21, p. 548, where we find the following:

Rock stamped, 297,030 tons.

Product of "mineral," 5,089,700 lbs.

Product of refined copper, 71.78% of the mineral.

Yield of rock, 12.3 lbs. copper per ton, or 0.615%.

Items of Cost per Ton of Rock Stamped.	
Mining, selecting and breaking, and all expenses, including taxes	$0.953
Transportation to mill	0.039
Stamping and separating	0.258
Total working expenses at mine	$1.25
Freight, smelting, etc.	.18
Construction account	.11
Total expenditures	$1.54

The stamping was done with five Leavitt steam-stamps, having 18-in. steam cylinders, each averaging 200 tons per day of 24 hrs. The rock is amygdaloid carrying native copper, and is stamped to pass a ⅜-in. screen. The stamps, it will be seen, are quite different from the California stamp batteries of light stamps. The details of the milling cost were:

Labor, including salaries, per ton	$0.096
Coal ($3.15 per ton)	0.119
Supplies, castings, oil, tools, etc.	0.034
Fire insurance, etc.	0.008
Total cost per ton	$0.257

Strictly speaking, the cost of handling the rock on the surface before reaching the stamps should be included under cost of milling; and 7 cts. covers this cost, including transportation, selecting poor rock, and breaking rock to pieces about the size of broken coal ready for the stamps. The total cost of milling is, therefore, about 33 cts. per ton.

The Isle Royale Copper Co. (Lake Superior) in 1901 mined and stamped its rock at the following cost:

Mining, cost per ton	$1.200
Rock house	0.109
Transportation	0.055
Stamping	0.249
Surface expense	0.039
Office expense	0.030
Incidental	0.181
Total per ton	$1.863

There were 201,951 tons of rock hoisted, of which 185,175 tons were stamped, the yield being 11.75 lbs. of copper per ton.

A RAILWAY WATER TANK FAILED at Frankfort, Ind., on Nov. 19. The cause of the failure is not definitely stated, but it appears that the steel hoops gave way. The tank was on a low tower.

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The construction of a 1,000-ton barge canal from Lake Erie to the Hudson will be perhaps the most important subject before the New York legislature when it assembles at the opening of the new year. Press dispatches from Albany on Nov. 29 stated that Gov. Odell had decided to recommend in his message that the Lake Ontario route be adopted for the canal, effecting a saving to the State of over $20,000,000. As our readers will recall, the adoption of this route in preference to the present Erie Canal route was strongly urged in this journal in our issue of Oct. 2. Later reports deny that the Governor has committed himself in favor of any route; but at least this indicates that the relative routes are to have consideration, and the State is not to be saddled with the additional cost of the interior route unless its advocates can prove that it will be worth its greater cost.

A number of years ago a passenger steamer of the Fall River Line took fire while lying at the wharf, and notwithstanding the utmost efforts of those on board, she burned so rapidly that the few persons who happened to be on board barely escaped with their lives. We said in comment at the time that the occurrence was an object lesson which ought to be heeded as to the certainty of a great holocaust should one of these floating fire-traps take fire during a trip when crowded with passengers.

But object lessons go too often unheeded, even by those who most ought to profit by them. As stated in another column, a new million-dollar passenger steamer is to be built for the Fall River Line, and we learn that its interior finish will be "particularly elaborate, the woodwork being pine, decorated with carving, parti-color frescoes and heavy gilding." In other words, so far as at present appears, the new vessel will be another floating fire-trap. If any one doubts the accuracy of this term, we invite their attention to the records of the terrible fire which destroyed the docks and several vessels of the North German Lloyd Steamship Co. at Hoboken in the summer of 1900. That fire took place on board ocean steamers, which in comparison to a typical American river or Sound steamboat are like a building of slow-burning construction compared to a typical "balloon frame" structure. That fire occurred, moreover, in a harbor where the most perfect fire-fighting facilities in the world were at command; yet it was not until the lapse of many hours and the sacrifice of many lives that the fires on these steamers were finally quenched.

Why should not the Fall River Line managers heed such lessons as these in the construction of their new vessel? Instead of lavishing money on a mass of "pine decorated with carving and heavy gilding," why not devote a little expenditure to safeguarding the lives of passengers? It is to be noted that even the poor excuse of economy, which used to be given in defence of fire-trap construction, does not now hold. The soft and readily inflammable woods like pine are now almost as high-priced and costly as the hard woods. It is true that the latter are more expensive to work with carvers and jig saws; but "floating palaces" can be built without the use of these forms of decoration, and with no loss in artistic effect.

We believe it is entirely within the resources of engineers and marine architects to build a river or Sound steamer in which passengers' lives will be fairly secure against danger from fire. A large part of the upper works and interior finish could be made of incombustible materials, and where the use of wood is necessary it could be treated by some fire-retardent process. We do not urge actual fireproof construction, of course, as weight and other considerations would make many methods used in buildings inapplicable on board vessels. What we do advocate is such sensible use of present-day methods of retarding the spread of flames as shall make it possible to extinguish a fire should one start on board such a vessel, or at least enable passengers to escape with their lives in advance of the conflagration's spread.

For weeks past the great city of Chicago has compelled the children in its schools to either carry water to school or go thirsty during school hours on account of the dangerous character of its water supply. This, of course, means that the whole population of the city, so far as it drinks lake water, has been in constant danger of typhoid fever. The following extract from the weekly "Health Bulletin" (Nov. 22), shows that while a portion of the water supply is now safe, the improvement is considered to be of uncertain duration, while some 750,000 people are as badly off as ever:

> This improving character of the water supply—continuous now during the last three weeks—has been brought to the attention of the Board of Education, with the suggestion that it would be safe for the board to allow the water to be used in the public schools in many areas of the city. In the district supplied by the Carter H. Harrison tunnel, containing a population of about 410,000, and in that supplied by the Four-Mile tunnel, containing about 200,000 population, the water has been uniformly good since the first of the month. On the other hand, in the two districts supplied solely or chiefly by the Chicago Ave. tunnel, containing an aggregate population of 750,000, the water continues unsafe for drinking purposes without being first sterilized. The supplies from the Lake View and the Hyde Park tunnels are variable in quality, but have been safe for from two-thirds to more than four-fifths of the time.
>
> The suggestion of the Commissioner was, in effect, that the school board should cause the water to be turned on in the schools in certain districts to be specified from day to day. The chemical examinations, which are used to base the characterizations upon, are completed about 11 o'clock each morning, and it was offered to telephone the results to the proper school officials at once. The Commissioner feels further warranted in making this suggestion, because at this season of the year children do not drink such large quantities of water is in warm weather, and the supply of more than a million of the population of the city is safe enough to justify action looking to the relief of a majority of the children from further water privation.

While such statements as those just quoted incline one to use strong language regarding the many delays in securing a safe water supply for the whole city, the zealous care with which Dr. Reynolds, the commission of health, and his chemical and bacteriological staff, do all in their power to guard the city from danger arouses admiration for those officials and for the modern scientific methods which make such care possible.

The Interborough Rapid Transit Co., which is the title of the corporation that is constructing and is to operate the New York Rapid Transit Ry., has leased the Manhattan Elevated Ry. system for 999 years. This will bring the entire long-distance passenger business of the old city of New York under one ownership and management; and it is prophesied that at no distant date absorption will be effected of all the surface street railway lines, which are now operated by the Metropolitan Traction Co., and of the surface and elevated transit lines in the Borough of Brooklyn, which are now controlled by the Brooklyn Rapid Transit Co. Such a result would be in accord with the tendency in street railway matters in all American cities; in fact the same tendency is plain in all of the "public utilities." As has been many times pointed out in these columns, this means that competition cannot be relied on to protect the interests of the public in this field; or, in other words, the supply of gas, water, electric current, passenger transportation and certain other necessities and conveniences of city life are natural monopolies and should be so recognized by all who have to do with municipal government. These natural monopolies may be either owned and operated by the city directly or entrusted to a private corporation; but where the latter course is chosen provision ought to be made for supervision by public authority to the end that good service may be furnished at a reasonable price.

Is granite a mineral? This question arises in a suit brought by the Northern Pacific R. R. Co. against J. A. Soderberg, of the state of Washington. The suit has arisen from a controversy over lands within the land grant of the railroad company. The government, as has been customary in making grants of land to railways in the West, doubtless reserved all "minerals;" and now the question arises whether granite is or is not a mineral.

Scientifically speaking, a true granite is a rock composed of three minerals, quartz, feldspar and mica; the latter often being replaced by hornblende.

In the sense of the term as used in mining transactions, a "mineral" is one of the metal-carrying minerals, such as galena, zinc blende, etc.; and in a still narrower sense a "mineral" must contain some one or more of the rarer metals, thus excluding iron ores such as hematite and the like.

Viewed in any light, except that of the purist in language, granite is not a "mineral," and even the purist must concede that it is three minerals forming a building stone which in no ordinary sense of the term can have been included in any reservation of the "minerals" of a grant of land. If granite were a "mineral" under the terms of the land grant, then the very soil forming the land is just as truly a mineral; for if of clay, it is disintegrated feldspar; if sand, it is quartz; and if alluvium, it is a mixture of both with some vegetable matter.

A suit of this sort, in which the whole case rests upon the meaning of a single word, is not uncommon; but such a suit is doubtless the outcome of ignorance on the part of some lawyer—an ignorance begotten of too great reliance upon such dictionary definitions, as one in the "Century:" "Mineral, any constituent of the earth's crest."

We give up an unusually large proportion of the space in this issue of Engineering News to a valuable paper by Mr. John Wolf Thurso on "Modern Turbine Practice." We commented in our issue of Oct. 23 upon the lack of really first-class and practically useful and reliable literature in this department of hydraulic engineering, and we have heard no dissent from the conclusions which we

then expressed. Mr. Thurso speaks in the light of extensive experience in water-power installations, and while some of his criticisms may seem severe, they are in our opinion calculated to work benefit to both builders and users of hydraulic motors in the United States.

In a later issue we expect to present a second paper by Mr. Thurso dealing in a practical way with various features of water-power installation aside from the turbines. These two articles, with much additional matter for which space could not be spared in the columns of Engineering News, we shall later issue in book form.

Commenting on the failure of a warehouse floor in Minneapolis, described in our last issue, the "Providence Journal" makes the following very sensible argument for the employment of engineers in connection with building construction:

The lesson is obvious—it is not wise to intrust engineering questions to men who are not engineers. The architect has a field separate from that of the engineer. There are few engineers who pretend to understand architecture, and it may be taken for granted that all architects are not as competent in the calculating of stresses as engineers. Modern business and office buildings and warehouses present many problems in engineering, and life and property are dependent upon their correct solution. Therefore the various elements should be inspected by engineers of good standing.

The pitting of boiler plates has long been a fruitful source of trouble to engineers and a great deal has been written concerning its causes and remedies. Another trouble due to obscure causes concerning which comparatively little is to be found in engineering literature is the pitting of the backs of cast-iron propeller blades near the tips. This pitting is so rapid and severe that the blades of large propellers are sometimes eaten clear through to the front face and the outer tip of the propeller is eaten off for several inches leaving a rough, jagged surface which moves through the water with great friction.

At a recent meeting of the Pacific Coast Electric Transmission Association this subject was brought forward, and it was shown that the backs of turbine blades and centrifugal pump runners are sometimes pitted in a similar way. Specimens of deeply pitted nozzles used with impulse water wheels were also shown, and it was suggested that the pitting might be due to a similar cause.

We bring the subject forward in the hope that some of our readers may be able to furnish us some notes of experience concerning the causes of this corrosive action, the extent to which it occurs in various fields, and the best methods of counteracting it. A great deal is heard about the efficiency attained by turbines and centrifugal pumps and propellers when new; but it is important to know to what extent this efficiency is maintained in service. When corrosion proceeds as far as in some samples we have seen, a large part of the applied energy must be expended in friction and churning of the water.

HEAT RESISTANCE, THE RECIPROCAL OF HEAT CONDUCTIVITY.*

During a recent study of the heat conducting power of various substances used for heat insulation, especially in cold storage warehouses, the writer recently discovered that the comparison of results obtained by different experimenters would be facilitated if these results were reduced to a common basis of coefficients of heat resistance, instead of being expressed, as is usual, in the number of British thermal units transmitted per hour, or per day, by each square foot of surface per degree of difference of temperature of the air adjoining the two surfaces.

The use of these figures representing *resistance* instead of those representing *conductivity* is analogous to the usual practice in electrical calculations, the chief advantage being that resistances in series may be added together to obtain total resistance, while the conductance of several wires or other bodies acting in series cannot be added to obtain the total conductance. Thus, if R_1 and R_2 are the resistances of two wires arranged in series, or one after the other, their total resistance is $R_1 + R_2$. If c_1 and c_2 are the conductances of these two wires, or the reciprocal of the resistances, $= \frac{1}{R_1}, \frac{1}{R_2}$, respectively, their total conductance is not $c_1 + c_2$, but $1 \div \left(\frac{1}{c_1} + \frac{1}{c_2}\right)$.

The meaning of this, as applied to heat conductance may be made clear by considering the following hypothetical case. Suppose that in testing the heat conducting power of a certain substance, say a sheet of cardboard, we find that its conductivity, expressed in B. T. U. per sq. ft. per hour per degree of difference of temperature is 0.8 and that a sheet of felt tested in the same way gives the figure 0.4; placing a felt between two boards we obtain 0.2; two felts between three boards, 0.1143; three felts between four boards, 0.08; four felts between five boards, 0.0615. We can find no satisfactory relation between the several figures by adding or subtracting them, but by taking their reciprocals we find they are entirely in harmony, as is shown in the following table:

	Conductivity.	Difference.	Reciprocal.	Difference.
1 sheet cardboard	0.8	0.0	1.25	0.0
1 sheet felt	0.4	0.4	2.5	1.25
2 cardboards, 1 felt....	0.2	0.2	5.0	2.5
3 " 2 "	0.1143	0.0857	8.75	3.75
4 " 3 "	0.08	0.0343	12.50	3.75
5 " 4 "	0.0615	0.0185	16.25	3.75

The last column shows that the resistance to transmission of heat of any combination of these elements is simply the sum of the separate resistances of the several elements. Of course, such a perfectly harmonious result can never be expected in actual tests of heat insulators, such as may be obtained in tests of electrical resistances, for the reasons: (1) That it is impossible to obtain uniform conditions in and on the two surfaces of any non-conductor of heat which is exposed to the atmosphere, and (2), that in an assemblage of elements such as described some of the surfaces are in contact with other elements, while others are exposed, this difference of conditions making a great difference in the resistance of the surface to transfer of heat.

Authorities on the subject of heat transmission generally agree that the resistance to the passage of heat through a plate consists of three separate resistances, viz.: the resistances of the two surfaces and the resistance of the body of the plate, which latter is proportional to the thickness of the plate. It is probable also that the resistance of the surface differs with the nature of the body or medium with which it is in contact. Thus a very rough surface on a metal plate would be likely to transfer more heat to adjacent air than a smooth surface would, since it has a greater area in actual contact with the air, while two rough surfaces of metal touching each other would transmit from one to the other less heat than two smooth surfaces.

A complete set of experiments on the heat resisting power of heat insulating substances should include an investigation into the difference in surface resistance when a surface is in contact with air and when it is in contact with another solid body. Suppose we find that the total resistance of a certain non-conductor may be represented by the figure 10, and that three similar pieces all give the same figure. Two pieces in contact give 16 and three pieces in contact give 22. What is the resistance of the surface exposed to the air in either piece, of the surface in contact with another surface, and of the interior of the body itself? Let the resistance of the material be represented by A, that of the surface exposed to the air by a, and that of the surface in contact with another surface by c.

We then have for the three cases,

Resistance of one piece.....	$A + 2a = 10$
" of two pieces 2	$A + 2c + 2a = 16$
" of three pieces.....3	$A + 4c + 2a = 22$

These three equations contain three unknown quantities. Solving the equations we find $A = 4$, $a = 3$, and $c = 1$. Having these results we can easily estimate what will be the resistance to heat transfer of any number of layers of the material, whether in contact or separated by air spaces.

The writer has computed the figures for heat resistance of several insulating substances from the figures of conducting power given in a table published by Mr. John E. Starr,* in a paper on "Insulation for Cold Storage," published in "Ice and Refrigeration" for November, 1901. Mr. Starr's figures are given in terms of the B. T. U. transmitted per square foot of surface per day per degree of difference of temperature of the air adjacent to each surface. The writer's figures, those in the last column of the table given herewith, are calculated by dividing Mr. Starr's figures by 24, to obtain the hourly rate, and then taking their reciprocals. They may be called "coefficients of heat resistance" and defined as the reciprocals of the B. T. U. per square foot per hour per degree of difference of temperature.

Analyzing some of the results given in the last column of the table, we observe that, comparing Nos. 2 and 3, one inch added thickness of pitch increased the coefficient 0.74; comparing Nos. 4 and 5, 1½ ins. of mineral wool increased the coefficient 1.11. If we assume that the 1 in. of mineral wool in No. 4 was equal in heat resistance to the additional 1½ ins. added in No. 5, or 1.11 reciprocal units, and subtract this from 5.22, we get 4.11 as the resistance of two ⅞-in. boards and two sheets of paper. This would indicate that one ⅞-in. board and one sheet of paper give nearly twice as much resistance as 1 in. of mineral wool. In like manner any number of deductions may be drawn from the table, and some of them will be rather questionable, such as the comparison of No. 15 and No. 16, showing that 1 in. additional sheet cork increased the resistance given by four sheets 6.67 reciprocal units, or one-third the total resistance of No. 15. This result is extraordinary, and indicates that there must have been considerable differences of conditions during the two tests.

For comparison with the coefficients of heat resistance computed from Mr. Starr's results we may take the reciprocals of the figures given by Mr. Alfred R. Wolff (Kent's "Mechanical Engineers' Pocket-Book," p. 534), as the result of

*Consulting Engineer, 258 Broadway, New York.

*The above editorial is presented by Mr. Wm. Kent, of the editorial staff of this journal, as a paper before the American Society of Mechanical Engineers at its meeting in New York this week.

Heat Conducting and Resisting Values of Different Insulating Materials.

No	Insulated material.	Conductance B.T.U. per sq.ft. per day per degree of difference of temperature.	Coefficient of heat resistance.
1.	⅝-in. oak board, 1-in. lampblack, ¾-in. pine board (ordinary family refrigerator)	5.7	4.21
2.	¾-in. board, 1-in. pitch, ⅞-in. board.	4.89	4.91
3.	¾-in. board, 2-in. pitch, ⅞-in. board	4.25	5.65
4.	⅞-in. board, paper, 1-in. mineral wool, paper, ⅞-in. board	4.6	5.22
5.	⅞-in. board, paper, 2½-in. mineral wool, paper, ⅞-in. board	3.62	6.63
6.	⅞-in. board, paper, 2-in. calcined pumice, ⅞-in. board	3.38	7.10
7.	Same as above, when wet	3.90	6.15
8.	¾-in. board, paper, 3-in. sheet cork, ⅞-in. board	2.10	11.43
9.	Two ⅞-in. boards, paper, solid, no air space, paper, two ⅞-in. boards	4.28	5.61
10.	Two ⅞-in. boards, paper, 1 air space, paper, two ⅞-in. boards	3.71	6.47
11.	Two ⅞-in. boards, paper, 1-in. hair felt, paper, two ⅞-in. boards	3.32	7.23
12.	Two ⅞-in. boards, paper, 8-in. mill shavings, paper, two ⅞-in. boards	1.35	17.78
13.	The same, slightly moist	1.80	13.33
14.	The same, damp	2.10	11.43
15.	Two ⅞-in. boards, paper, 3-in. air, 4-in. sheet cork, paper, two ⅞-in. boards	1.20	20.00
16.	Same, with 5-in. sheet cork	0.90	26.67
17.	Same, with 4-in. granulated cork	1.70	14.12
18.	Same, with 1-in. sheet cork	3.30	7.27
19.	Four double ⅞-in. boards (8 boards), with paper bet. three 8-in. air spaces	2.70	8.89
20.	Four ¾-in. boards, with 3 quilts of ¼-in. hair bet. papers separating boards	2.52	9.52
21.	⅞-in. board, 6-in. patented silicated strawboard, finished inside with thin cement	2.48	9.68

German experiments on the heat transmitted through various building materials, as below:

K = B. T. U. transmitted per hour per sq. ft. of surface, per degree F difference of temperature.

C = heat resistance = reciprocal of K.

	Thickness.	K.	C.	Difference.
Brick wall	4-in.	0.68	1.47	0.70
	8-in.	0.46	2.17	0.86
	12-in.	0.32	3.03	0.82
	16-in.	0.26	3.85	0.70
	20-in.	0.23	4.55	0.45
	24-in.	0.20	5.00	0.75
	28-in.	0.174	5.75	0.92
	32-in.	0.15	6.67	1.08
	36-in.	0.129	7.75	0.95
	40-in.	0.115	8.70	
Wooden beam construction, planked over or ceiled: As flooring		0.083	12.05	....
As ceiling		0.104	9.71	....
Fireproof construction, floored over: As flooring		0.124	8.06	....
As ceiling		0.145	6.90	....
Single window		1.030	0.97	....
Single skylight		1.118	0.89	....
Double window		0.518	1.93	....
Double skylight		0.621	1.61	....
Door		0.414	2.42	....

The irregularity of the differences of C for each increase of 4 ins. in thickness of the brick walls indicates a difference in the conditions of the experiments from which the figures were derived. The average difference of C for each 4 ins. of thickness is about 0.80. Using this average difference to even up the figures we find the value of C is expressed by the approximate formula C = 0.70 + 0.20 t, in which t is the thickness in inches. The revised values of C, computed by this formula, and the corresponding revised values of K are as follows:

	Thickness.	C.	K.	K, original figures.	Difference.
Brick wall	4-in.	1.50	0.667	0.68	0.013
	8-in.	2.30	0.435	0.46	0.025
	12-in.	3.10	0.323	0.32	0.003
	16-in.	3.90	0.256	0.26	0.004
	20-in.	4.70	0.213	0.23	0.017
	24-in.	5.50	0.182	0.20	0.018
	28-in.	6.30	0.159	0.174	0.015
	32-in.	7.10	0.141	0.15	0.009
	36-in.	7.90	0.127	0.129	0.002
	40-in.	8.70	0.115	0.115	0.0

In conclusion we would propose to engineers and others who have to make tests in which heat transmission is involved the adoption of a standard for expressing heat resistance or the heat insulating power of various substances as follows:

THE COEFFICIENT OF HEAT RESISTANCE OF A SUBSTANCE IS EQUAL TO UNITY DIVIDED BY THE NUMBER OF BRITISH THERMAL UNITS TRANSMITTED IN ONE HOUR BY A SLAB ONE SQUARE FOOT IN AREA, AND ONE INCH THICK PER DEGREE FAHRENHEIT OF DIFFERENCE OF TEMPERATURE BETWEEN THE TWO FACES OF SAID SLAB, BOTH SURFACES BEING EXPOSED TO STILL AIR.

The subject of the heat insulating power of different substances is of immense importance in refrigerating work, and it is to be hoped that when further experiments with such substances are made their results may be reported in the manner here suggested, and that conclusions be drawn by the experimenters from the reciprocal values or "coefficients of heat resistance" here described.

LETTERS TO THE EDITOR.

What Constitutes an Engine Load?

Sir: In court, on a grade-crossing case, where one railway had its maximum grade at the crossing, one party contended that an engine load was such a load as the engine under motion could haul over the "maximum grade." Their opponents were equally as positive that it meant what an engine could start anywhere on the line; of course, conditions of track to average the same in both cases. The authorities we have in the office—except Gordon—give no definite information on the subject. Is there law or custom that determines the question, or is it a debatable one whenever it comes up?

Respectfully, A. C. T.

Perry, O. T., Nov. 22, 1902.

(The latest and best practice in railway location (and operation) is to make what the locomotive can haul the criterion in fixing the engine load. This permits the use of steeper grades at points where the momentum helps the train to climb the hill. Of course such "momentum grades" must be used with discretion. They would not be allowed, for example, at a point where trains were frequently obliged to stop, as at a grade crossing.—Ed.)

Office Hours for Draftsmen.

Sir: Please inform the writer through your columns what are the average hours for first-class draftsmen employed by general engineering firms—men capable of originating ideas and completing drawings.

Would be pleased to hear through your columns from draftsmen interested in this question.

New York, Nov. 26, 1902. "Short Hours."

(In New York city, where the distance between homes and places of employment averages much greater than anywhere else in the United States, office hours are commonly from 9 a. m. to 5 p. m., and the hour's "nooning" is as often as not omitted. In other localities it is usual to begin work at 8 a. m.; and nine hours' work for the drafting room is the rule, we believe, in many manufacturing concerns where shop employees work ten hours. For mere routine copying a draftsman may be able to do good work continuously for nine or even ten hours a day and maintain his health, but where intelligent brain work is wanted of a draftsman, and rapid, energetic work is the rule, employers will gain little or nothing by requiring more than eight hours a day. —Ed.)

Some Legends of Blast-Furnace Cremations.

Sir: Your account of the Alliance Iron Furnace, Fayette county, is your issue of Nov. 20, includes a myth of Peter Marmie and his hunting dogs. This furnishes an excellent instance of how a story travels, and is appropriated by different communities, like that modern story about the three great liars known to history, Ananias being one and the person roasted being termed the other two. That hunting story is told around Lancaster county, Penn., about Peter Grubb, an ancestor or of the same line as the late American Minister to Spain. The Grubbs and the Colemans have been interested in the iron business there since "before the war"—not the Civil, but the war of 1776.

This Peter Grubb, according to tradition, was a hard-drinking, hard-riding squire (same as Peter Marmie), and after one hunt, in which the dogs failed to round the deer, he was so disgusted that, in his anger, he picked up each dog by the tail and threw it into the open-top blast furnace. Lebanon county, Pa., has been in the hands of one family for so long a period that it preserves and manufactures traditions as the Southern sections do. It is jocularly designated by outsiders as the "Grand Duchy of Cornwall and Lebanon."

These legendary stories, suggesting the "Hounds of Baskerville," by Doyle, are matched in Pittsburg. The story is told there of an Irish top-filler who fell into the furnace; some 18 hours later a cast of metal showing an unexpectedly high phosphorus contents suggested an inquiry, and the fate of the top-filler was learned. Being a Catholic, the slag made at the time of the high phosphorus cast was appropriately buried according to the last rites of the church.

As the phosphorus made the cast of metal of less value, precautions were instituted to prevent loss of life in that manner in future.

L. F. G.

Baltimore, Md., Nov. 25, 1902.

An Explanation of Unaccounted-for Water.

Sir: Something more may, I think, be said in reply to the question of R. S. H. on p. 451 of your paper: Is there any reason for a record of only 40% and 50% of the water paid for by a municipality finally reaching the uses of the water-takers?

As is now coming to be recognized, this is a common occurrence in the United States, in this year of progress, 1902. But R. S. H. may find the answer to his question in an article entitled "Thrift in the Operation of Water-Works," on p. 102 of Proceedings of the American Water-Works Association, for the year 1901. And to repeat here the one salient feature of the sought-for answer, it may thus be formulated: Because, as a rule, no proper account is now kept of inflow and outgo of municipal water supplies, and none such *can* be kept until the quantity of water put into the mains is measured, and then traced through the whole of the delivery system, from the master-meter, or meters, to the consumers faucets or other intake; just as is done in gas service and in electrical service.

So long as no account is kept of the waste of water that is out of sight, hence out of mind, going on [illegible] the distribution mains, and up-stream from the [illegible] meters, so long will there be an improper amount [illegible] on the lines described. House-meters naturally [illegible] control, affect, or stop this waste; only intelligent [illegible] tinued, patient work can do it. But that it can be [illegible] vented, experience has shown. Out of over 50 miles [illegible] steel-riveted conduits and other mains of the Ea[illegible] Water Co., acting under over 300 ft. pressure in pl[illegible] the leakage for years, as determined by daily meter[illegible] and outflow, was never allowed to surpass 1%.

The sought-for remedy is a trite one. "There [illegible] no ghost, my lord, come from the grave," nor yet a [illegible] of science, to tell it to us. Eternal vigilance and a proper system of accounting is the price of liberty from [illegible] waste and extravagant expenditures in the operation of water-works, as it is in most of the other affairs of life.

"2 Wall [illegible]

New York, N. Y., Nov. 28, 1902.

Floorbeam Hangers; the Relative Safety of Buildings.

Sir: Referring to your review of a Minneapolis warehouse failure in your issue of Nov. 20, it may be noted that the hangers were a so-called "standard" hanger manufactured, I understand, by a Cleveland firm.

The only thing about them that appears to be standard is that the section appears to be identical for all sizes of wooden beams from an 8 × 10-in. to a 12 × 20-in., the stirrup being a little longer or shorter to fit the beam.

As few of these hangers are suitable as generally furnished for heavy work from the standpoint of safety, it may not be amiss for your journal to call attention to the general fact, since what little education the general public gets in the engineering line is largely from papers like yours.

That the unlucky architect in the case noted seems to have pinned his faith to an architectural iron works employing less engineering ability than could be found in a country blacksmith shop is a disappointing feature of too rigid an adherence to the general custom of allowing the steel contractor to furnish whatever he sees fit.

A point which you failed to discuss in your editorial is the degree of safety of a building or structure. For example, a business man sees three or four buildings constructed from practically identical plans; in one (as in a case observed by the writer) the beam hangers are a trifle thinner than in the other two or three, and the result is an expensive collapse in the former case, while the other two or three buildings have proven "satisfactory" (?) thus far as regards standing up, with a liberal factor of safety something greater than unity and presumably less than two! The average business man neither sees clearly nor understands the difference between such a "satisfactory" building and one that is really *safe* from the engineer's standpoint.

A discussion of the liability of an owner for damage to a tenant through faulty construction would (as is invariably the case where dollars and cents are involved) materially assist in making your explanation lucid and interesting. Yours truly, C. A. P. Turner.

816 Phoenix Bldg., Minneapolis, Minn., Nov. 24, 1902.

(Without pretending to pose as an authority on matters of law, we should suppose that the responsibility of a landlord for damages to a tenant through defective construction of a building was clear. Of course if the landlord could show that he had used due diligence to secure a safe structure so that the accident occurred through no fault of his, he might escape liability. From the point of view of public policy, however, we believe the tendency is toward making the owner responsible, since such fixing of responsibility tends to make all owners more careful to secure safe construction.—Ed.)

Notes and Queries.

Apropos of the 40-year-old Bollman truss bridge, illustrated in our last issue, many of the readers of Engineering News may be interested to learn that a wooden highway bridge, 90 years old, is still in use at Waterford, N. Y. It is described as follows in a recent published account of a visit to the vicinity by the senior class of the Thayer School of Civil Engineering:

At Waterford there is a fine specimen of a wooden highway bridge built in 1813, by Theodore Burr, across the Hudson River. It has wooden trusses of the once familiar type, each strengthened by a timber arch. The timbers are still sound and serviceable. It has recently been reinforced for modern trolley-car traffic by thickening the arches and putting in some iron suspender rods, but otherwise it is the same bridge, now nearly 90 years old. There are four spans of 175 ft. in the clear, resting on thick piers, so that the entire length is nearly 800 ft. There are three lines of trusses and two roadways, each 17 ft. wide, c. to c. of trusses.

J. W. S., Spokane, Wash., asks for a practical method of developing power by a current water wheel mounted on a float which is anchored in a stream of swift current.

We believe a manufacturer of mining machinery in the

West some years ago advertised an apparatus of this sort in which a long, narrow, flat-bottomed boat had endless sprocket chains running over wheels at the bow and stern. These wheels carried paddles which were immersed in the water when moving toward the stern. The force of the water acting against these paddles was sufficient to develop considerable power. It was proposed to use hydraulic, pneumatic or electric transmission to deliver the power where it was wanted.

If any of our readers can furnish particulars of an actual installation of this sort, or of any method of developing power from rapids by the force of the current, we shall be pleased to hear from them.

A WASHINGTON POWER DEVELOPMENT SCHEME contemplates adding to the Snoqualmie Falls system by utilizing the power of the White River. The water of this river is to be diverted and conveyed by canal eight miles to Lake Tapps. The level of this lake will be raised, and a large storage reservoir thus formed. From here the water leads to the power house, giving a head of 450 ft. The tail water is to discharge into Stuck River. Electric generators in the power station feed a line, which five miles away connects with the existing Snoqualmie Falls transmission line running to Seattle and Tacoma. Branch lines may also be run from the enlarged system to Everett and Portland. The initial installation on White River is to be of 10,000-HP. capacity, but arranged so that by installing additional machinery the capacity can be raised to 50,000 HP. The minimum amount of water available is slightly in excess of this, it is stated. The project is put forward by the Snoqualmie Falls & White River Power Co., of which Mr. Chas. H. Baker, of Seattle, Wash., is President and Chief Engineer.

UNDERGROUND WATER RIGHTS IN CALIFORNIA have been defined more clearly than ever before by the State Supreme Court in a decision rendered on Nov. 7, 1902, in Katz vs. Walkinshaw. The case was an appeal from a judgment of non-suit in an action to enjoin the diversion of artesian water, for distant use, from lands under cultivation. The wells were located on land near that under cultivation, and so drew down the water as to make or threaten to make the cultivated lands desert. The Supreme Court held that while the underground flow from the high lands above could not be regarded as a well-defined stream subject to riparian laws, neither could it be held that the ownership of the land in which the wells were located entitled the owner to make a desert of surrounding lands, particularly when the water was for distant uses. In the decision of the Supreme Court, which was unanimous, the classic British cases were reviewed, but most stress was laid upon the series of decisions involving underground water rights on Long Island, as affected by the wells forming a part of the water supply of Brooklyn Borough, Greater New York. In a land with a scanty water supply, like Southern California, the law should go even further than in the Eastern United States and Great Britain, with their relatively ample water supplies, in protecting tillers of the soil from having their lands damaged through underdrainage from adjacent wells. The lands and water rights in question in this California case were located in San Bernardino county, and the decision in full was published in the Los Angeles "Journal" for Nov 15, 1902.

AN EXPERIMENTAL STEEL TRACKWAY IN NEW YORK CITY.

A short section of steel trackway is being laid on Murray St., New York City, as the result of a movement inaugurated some months ago by Gen. Roy Stone, of New York, acting for the Automobile Club of America. Steel trackways have not been tried very extensively, whether for city streets or for country highways. In Germany a good start has been made in the last six or eight years in experimenting with such trackways on country roads. As appears from a recent article in the "Organ für die Fortschritte des Eisenbahnwesens," some 50 miles of trackway have been laid there, mainly in the province of Hannover. Different styles of rail section and track construction have been employed on different stretches of road there, and some results of experience have been obtained. On city streets, however, very little has been done in building steel trackways, and practically nothing is known as to their value in such locations* or the comparative merits of different constructions.

*In an article on "Traction on Wagon Roads," in Engineering News of March 6, 1902, Prof. I. O. Baker gave the results of a number of traction tests on different kinds of roads and pavements, including a short piece of steel wheelway. This latter was of inadequate construction, however, so that no close conclusions can be drawn. In Engineering News of May 8, 1902, Prof. Baker very fully discussed "Steel Wheelways for Wagon Roads," and much of this applies also to such trackways in city streets.

For these reasons the Murray St. trackway is expected by those building it to be interesting and valuable both as a test object and as a matter of public education regarding steel trackways in city streets. The section at present being laid in Murray St., between Church St. and Broadway, a distance of about 400 ft., will be subject to very heavy traffic. One or two other pieces of trackway will probably be laid in New York City by the same parties, and will be located on streets carrying principally pleasure vehicles, automobiles, etc.

Fig. 1 is a cross-section through the pavement with the steel trackway placed in position. The rails, which are 12 ins. wide, are channel-shaped, and are laid flat with the flanges down; they are spaced 4 ft. 6 ins. in the clear, so that the extreme width of track between their outer edges is 6 ft. 6 ins. The two rails (the trackway is being constructed single-track) are tied together at intervals of about 13 ft. by ¾-in. tie-rods, over which gas-pipe separators are placed. The pavement of the street extends between and outside of the rails, as close to the latter as possible. Murray St. is paved with granite blocks, and the pavement is in fair condition. It is not apprehended that much trouble will be had from grooving of the pavement next the rails.

The method adopted by Gen. Stone to construct a foundation for the rails is briefly described as follows: On the line of the rail the pavement is taken out about 18 ins. wide and a longitudinal trench dug some 18 ins. deep. In the bottom of the trench is laid a continuous foundation course of granite blocks, like those of the street pavement, and the trench is then filled with broken stone of 1½-in. size and under. On the top of this body is placed a 3-in. layer of bank gravel, containing material in sizes from small gravel down to sand and loam; the gravel is intended to be such as to pack hard and solid. The rail is then bedded in the gravel, the adjacent lengths riveted together, the tie-rods bolted in place, and the rails rammed down to grade. Care is taken by tamping the material under the rail that a solid filling between the flanges is secured, as this must carry the load from the traffic. Finally the strip adjoining the rails on either side is repaved, the blocks being drawn up as close as possible to the rails.

The rail used is of a special section, rolled for the purpose of this experiment by the Carnegie plant of the United States Steel Corporation. Some of the high officials of this concern became interested in the work, and it was through their courtesy that rolls were constructed for this special shape, and the rails supplied. The section of the rail is seen to be very similar to that of a standard 12-in. channel, with the addition of a substantial bead along each edge of the flat back of the channel. This head is ⅝-in. high above the plane of the back of the channel, which is the "tread" of the rail. The purpose of the beads is to guide the wheels of the vehicles and prevent them running off the rails; at the same time they are low enough, and are given such a rounded form, that turning out may be as easy as possible.

The rail weighs about 25 lbs. per lin. ft. (the standard minimum section 12-in. channel weighs 20.5 lbs. per ft.). The necessary fittings are tie-rods and splices. The rail is rolled in lengths of

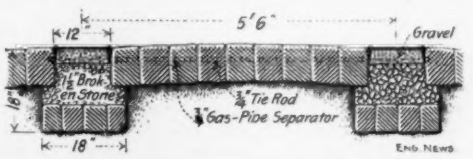


Fig. 1. Cross-Section of Murray St. Steel Trackway, Showing Construction.

40 ft. Joints are spliced with a 9 × 5-in. plate under the flat of the channel, fastened with three rivets in each rail, and a 10 × 3-in. plate on each flange, fastened with two rivets in each rail. The rivets in the splice of the tread are countersunk on top. Tie-rods are spaced about 13 ft.; they consist of a ¾-in. rod passing through both flanges of each rail and fitted with a nut on the outside, and a gas-pipe separator between the inner flanges of the two rails.

The cost per mile of this type of trackway has not yet been closely estimated. Since the rail weighs 25 lbs. per ft., or two rails 50 lbs. per ft., the weight of rails per mile of track would be 132 tons. At $35 per ton this would amount to $4,620, which the splices and tie-rods would bring

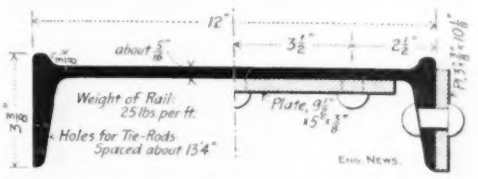


Fig. 2. Special Rail Section Used in Murray St. Steel Trackway.

up to say $5,000. The cost of laying would of course vary greatly with the conditions, but would probably exceed $2,500 in any case, if a foundation be used similar to that which was adopted in the present case. Thus the total cost of laying such a trackway would reach at least $7,500 per mile.

NOTES FROM WATER-WORKS REPORTS.

NEW BEDFORD, MASS.—The condition of the 48-in. riveted steel pipe line, laid in 1896, is described in the 1901 report of Mr. R. C. P. Coggeshall, Superintendent, as follows:

> The temporary discontinuance of the Quittacas pumping station in May afforded a good opportunity for an interior inspection of this line of pipe. Its entire length is 8¼ miles. That portion beginning at High Hill reservoir and extending 1⅞ miles toward the pumping station was emptied. As this was to be the first internal inspection which this pipe had received since it was placed in 1896, it was thought that possibly more or less painting might be needed. Preparation for this work was accordingly made. But this proved to be unnecessary, as scarcely any work other than that due to the examination was needed. When in use the water flows through this pipe at the rate of 1½ ft. per sec.—a rather slow velocity. So upon the bottom of the pipe there appears quite a collection of sediment which has settled from the water—generally in small hard lumps. When these are numerous the bottom has a pebbly appearance. Then along the sides, extending upwards from the bottom, an occasional blister was found. The largest was perhaps an inch in diameter. A touch would break the asphalt and expose the fresh steel beneath, which was bright and clear. When broken, all such places were touched with paint.
>
> All formations described were confined to the bottom part of the pipe, say a segment of 90°. The remaining three-quarters were as smooth as glass; perfectly bright and clear, and apparently as fresh looking as upon the day it was placed. The asphalt coating was found to be covered with the thinnest kind of scum, hardly thicker than frost, upon the window pane. The white paint marks upon the top made by the contractors during construction to identify each pipe are still clear and distinct. The above-described section was found to be in such good condition that the need of inspecting the remaining portion was not apparent; accordingly it was not emptied. As the result of this examination it is safe to say that it will be a long term of years before any work approaching a general overhauling of this line of pipe will be necessary.

PHILADELPHIA, PA.—The extensive water purification plants and allied improvements to the water-works are described at such length in the last city reports as to require some seventy pages, besides a number of illustrations. To the close of 1901 a total of $15,700,000 had been provided for settling reservoirs, filter beds, pumps, conduits and the like, and contracts had been awarded for filter beds with an aggregate capacity of 154,000,000 gallons, besides a 73,000,000 settling reservoir, 70,000,000 compensating reservoir, four filtered water basins with a combined capacity of 77,500,000 gallons, 90,000,000 gallons of pumping facilities, a 300,000,000-gallon filtered water conduit, and 31 miles of water mains. The work outlined above is under the charge of the following: Mr. Frank L. Hand, Chief of the Bureau of Water; Mr. Geo. S. Webster, Chief Engineer Bureau of Surveys; Mr. John W. Hill, Consulting Engineer; and Mr. Samuel Tobias Warner, First Assistant Engineer in Charge. Mr. Wm. C. Haddock is Director of Public Works.

CLEVELAND, O.—A study of the cost of the water-works to the end of 1901 is given in the last report of Mr. E. W. Bemis, Superintendent of Water-Works. The figures are classified by subjects and by years, and are then followed by a recapitulation showing the totals under each head, and also the sums, in like detail, that should be deducted on account of discarded pumps and other portions of the work, and also an account of

the decline in prices for pipe and pipe-laying, and for meters. The total cost of the works has been $10,818,776. The portions discarded cost $813,498. The deduction for decline in prices of pipe and pipe-laying (based on present values of $25 per ton for pipe and 21 cts. per hour for labor) amounts to $941,612 (original total cost, $6,162,141); and decline in meter prices is placed at $135,792 (original cost, $296,835). These two items give a total of $1,755,110 for material discarded and for decline in prices on pipe and meters, or 16.2% of the whole cost of the works to the end of 1901. During 1901 and 1902, pumping machinery and housing which originally cost $451,348, will be virtually abandoned, some being retained a few years for emergency use. If this item be added to the other deductions a total of $2,206,458, or some 20% of the original cost of $10,818,776, results as a beginning towards obtaining the present structural value of the works.

The foregoing takes no account of decline in prices for other portions of the works besides pipe and meters, nor for depreciation in plant still in use, but those two items make up nearly 70% the original outlay. Again, the estimates of original cost make no allowance for interest during construction (nor, apparently, for most of the engineering). After mentioning the facts already noted in this paragraph, Mr. Bemis states that 2% per year on the valuation of $9,063,667 for property now in use is probably a sufficient allowance, or may be too much "in view of the superior construction" since 1880. He then con-

Indeed, according to another theory of depreciation, a much less amount than 2%, if invested yearly in a sinking fund, bearing 2½ to 3% interest, would produce a sum equal to the present structural value of the plant by the time its deterioration and the progress of the arts may render it advisable to substitute new and better machinery, mains, etc.

To determine which theory of depreciation above referred to is the more correct, in the absence of a sinking fund in our water department, or to apply fully either theory, is not now attempted. It is believed, however, that the facts here given will throw much light not only on the vexed question of depreciation, but on the results of municipal ownership of the water-works in this seventh largest city of the United States.

We may add that the Cleveland works were built in 1853-4, but that the above figures take no account of their cost (save $20,569 for engineering, office expenses, and damages to the close of 1856) until the construction of the first lake crib and tunnel was begun in 1869. The total amount involved, however, could not have been large.

DAYTON, O.—The annual report of the water-works trustees for the year 1901 contains the decision, in full, in the electrolysis suit brought by the city against the City Railway Co. An extended review of the decision, which was in favor of the city, was given in our issue of April 17, but doubtless some of our readers would like to see a copy of the original. Mr. Chas. E. Rowe is secretary of the Dayton Water-Works.

ST. PAUL, MINN.—The report of this city for 1901 also contains a long special illustrated report on electrolysis, and an account of the steps preliminary to bringing suit against the street railway company to prevent conditions causing electrolysis. Mr. Paul Caulfield is secretary of the water-works.

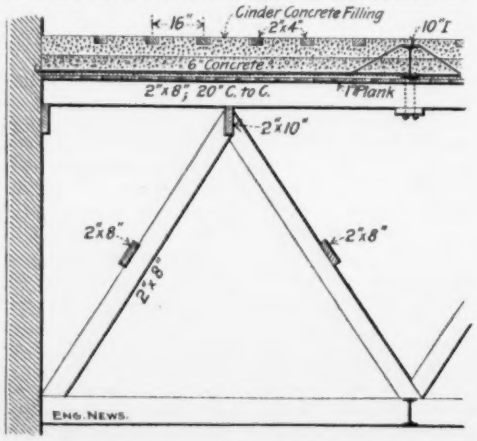
FAILURE OF A CONCRETE FLOOR AT CHICAGO.

The recent failure of a section of concrete floor in the new Paddington apartment building, Chicago, is a matter of considerable interest to engineers and contractors, but the accident appears not to have been due to any defect in the floor construction, but only to the careless removal of the supports used before the concrete had properly set.

The Paddington Building, 1632 Graceland Ave., is a four-story and basement building of considerable size, its four floors aggregating about 132,000 sq. ft. It was originally designed for floors with wooden joists, but later it was decided to make the building fireproof, and to use floors of concrete and expanded metal. The floor beams are 10-in. steel I-beams, and the floor spans vary from 13½ to 16 ft. Owing to the building having been planned for wooden floors, it was necessary to build the concrete floors to conceal the I-beams, but in buildings originally designed for this concrete construction the beams are usually arranged to come over partitions, and the surface of the concrete is made level with the top of the beams. In the case of the Paddington Building, the 6-in. concrete floor is level with the bottom of the beams, and this is covered with nearly 6 ins. of cinder deadening, in which are embedded the nailing strips for the floor.

The centering is shown in the accompanying sketch. Hangers hooked to the flanges of the beams carry rests for wooden joists, 2 × 8 ins., about 20 ins apart, across which is laid a decking of 1-in. planks. Under the joists, at the middle of the span, is a timber 2 × 10 ins., supported by inclined struts from the floor below. These struts are about 4 to 5 ft. apart, of planks, 2 × 8 ins., and braced longitudinally by horizontal planks, as shown. Sheets of expanded metal are laid across the lower flanges of the I-beams, or from the I-beam to a recess in the wall, being anchored to the wall. Upon this expanded metal sheeting are laid ½-in. round steel rods, 16 to 24 ins. apart. These are anchored into the walls, and some of them pass over the I-beams and into the next span (to which they are anchored by turning up the ends); these serve to tie the slabs of adjacent spans together.

The concrete is composed of 1 part Portland cement, 2 parts sand and 5 parts cinders, and it is put in quite wet. The time of drying out depends largely upon the weather. As a rule, the 1-in. planks are removed in two or three weeks, after which the concrete dries more rapidly; but the joists, longitudinal timbers and struts are left in for two or three weeks more, or until the ringing sound under a hammer blow indicates that the concrete has thoroughly set. This construction has been used for several million square feet



Construction of Concrete Floor and Timbering in the Paddington Building, Chicago.

of floor in many large and important buildings throughout the country, and we understand that only two accidents have occurred, the first being due to the builder overloading the wet concrete by storing a pile of cinders (for the deadening layer) on the floor.

The accident at the Paddington building occurred on the top floor, the others having already been built. The span which failed had been built (with others) on Oct. 29. On Nov. 20 the foreman for the floor contractors had some men taking out the plank decking, the timber supports, however, being left in place, as already described. One of the men was a laborer who had not been employed on this class of work before, and being left to himself to do some of the work, he proceeded to remove not only the decking, but the supports, which were intended to remain in for two or more weeks. He had removed these timbers under one of the 13½-ft. spans next to the wall, which span had already been loaded with nearly 6 ins. of the wet cinder concrete (1 cement to 6 cinders) deadening, which was to form the filling between the concrete and the wooden floor. The concrete being wet or green, collapsed. It bulged slowly until the expanded metal stripped from the beams, when the mass fell to the floor below, breaking through this and the other floors and going right through to the basement. The length of the hole in the top floor was about [illegible] ft. The man who had been removing the timbering was killed, and another man was injured. After the accident, the other spans from which the timbering had been prematurely removed were shored up.

The floors were designed for a load of 100 lbs. per sq. ft. The weight of the dry concrete is about 42 lbs. per sq. ft. of floor, 6 ins. thick; 84 lbs. per cu. ft.; when wet, however, the weight may be about 120 lbs. per cu. ft. There was a roof on the building, and as the weather had been chilly and wet for some time the concrete was slow in drying. Tests are to be made of the strength of the completed floors.

The architect of the building was Mr. D. H. Postle, and the general contractors were Leafgreen Bros. The contract for the floor construction was let to the Expanded Metal Fireproofing Co., of Chicago.

THE NEW YORK RAPID TRANSIT RAILWAY.

XIV.

Contract Section VII.

Contract sections VII. and VIII. of the Rapid Transit Railway were in the hands of one contractor, but only one section will be considered at a time. Section VII. extended from a junction with the main line at Broadway, near 103d St., ran easterly under private property to 104th St., then east along that street to Central Park, then under the north end of Central Park to 110th St. Section VIII. continued the line from 110th St. along Lenox Ave. to 100 ft. north of the center of 135th St. These were the first two sections of the East Side Line and were designed for two tracks. The contractors were Farrell, Hopper & Co., of New York city, who, however, sublet the work from 116th St. to 135th St. to John C. Rodgers, of New York city. The following description will take up the work of Section VII., which was for the most part deep tunnel work.

ROUTE AND STRUCTURE.—The East Side Line connects with the main line on Broadway at a point near 103d St., and thence curves onrth and east under private property to 104th St. The curve consists of a transition curve 150 ft. long, followed by 384 ft. of circular curve with a radius of 340 ft., ending with another transition curve 150 ft. long. Along 104th St. the line runs east on a tangent, and has a descending grade of 1.04%. As Central Park is approached the line changes to a transition curve 150 ft. long, followed by a 307-ft. circular curve with a radius of 580 ft., and ends with another transition curve of 150 ft., which swing it northward. Then follows a tangent under Central Park. The 1.04% descending grade continues throughout this second curve and tangent to a point about 540 ft. short of 110th St. Just before 110th St. is reached the tangent changes into curve turning northward. This last curve, or, rather, set of curves, is rather complicated in arrangement, and, although it takes the line into Section VIII., it will make the arrangement clearer to describe it all here. The two tracks have different curves. The right track has a curve 127 ft. long and 240 ft. in radius, compounded with another 329 ft. long and 1,299 ft. in radius. The left track has a curve 166.2 ft. long and 359.26 ft. in radius, followed by another 179.37 ft. long and 787.54 ft. in radius; these curves run into a tangent 255.3 ft. long, which leads to another curve 117.2 ft. long and 1,273.07 ft. in radius alike for both tracks.

All of Section VII. was double-track tunnel construction, and all except a short length of open-cut work at the north end was deep tunnel construction through rock. The tunnel cross-section adopted was shown in the preceding article on "General Description of the Work."* In brief, this cross-section has a flat floor, vertical sidewalls and a circular roof arch; the dimensions being, extreme width 25 ft., extreme height 18 ft., height of sidewalls 5½ ft., and radius of roof arch 12½ ft. The lining is of concrete.

FIXING OF CENTER LINE.—The fixing of the center line of any curved tunnel is a task of some complexity, and this complexity was greatly increased in the tunnel of Section VII. of the Rapid

*Engineering News, Feb. 20, 1902.

Transit Railway by the number and intricate arrangement of the curves. The location of the tunnel line underground was done from the shaft at 104th St. and Central Park West, the shaft near Broadway and the east portal in Central Park. Fig. 86 illustrates the mode of procedure followed by the engineers at the shaft at 104th St. and Central Park West. A working shaft S was sunk in the park just inside the sidewalk line

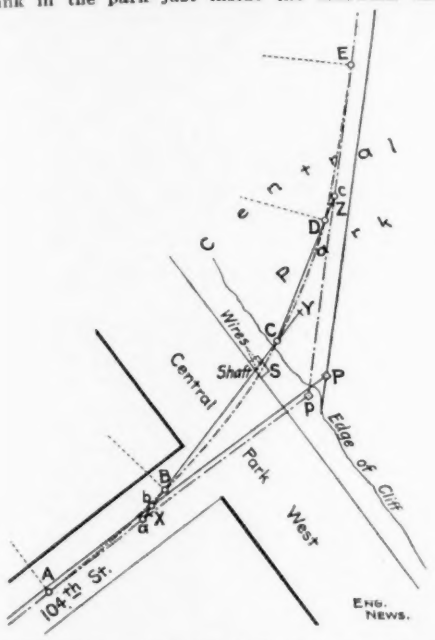


Fig. 86. Diagram Showing Method of Fixing Center Line for Central Park Tunnel.

of the bordering street known as Central Park West. The line A B C D E represents the curve of the adopted center line, A B and D E, being the two transition curves, and B C D being the circular curve. Since the chord B D of the circular curve did not pass through the shaft S, another chord B C was adopted which would do so.

It was impossible to produce the two tangents Ap and pE, to an intersection at p on account of numerous obstacles. Moreover,, the point p would have been inaccessible. Therefore, offset lines parallel to the tangents were run to an intersection at P. On account of the cliff near the western side of the park at this point, it was necessary to determine the distance from P to some point on the 104th St. offset line by triangulation. Two chords were chosen, passing respectively through the beginning (B) and the end (D) of the circular curve, meeting at the point C on the curve. The point C was accurately located on the surface by measurements from P. The point b was also located from the point previously established in 104th St. by triangulation. The angles of triangle b C P were measured as a check. With a transit at b, foresighting on C (incidentally remeasuring angle at b) the wires suspended in the shaft were moved into line. Fine piano wires were used reaching to within a foot or so of the bottom of the shaft. The distance between the wires was 7.9 ft. To each wire was attached a 25-lb. weight which hung freely in a tub of water. At the bottom of the shaft a transit was shifted into line with the wires, and two plugs were set as far apart as practicable within the limits of the excavation. The position of the plugs on the chord B C (or chord produced) was determined by measurements from one of the wires, the position of which had previously been determined by surface measurements. A plug was then located at C. When the first dropping was made the headings were in only a short distance; consequently extreme accuracy was not necessary or possible. The point C and the fixed direction B C enabled the engineers to produce the curve each way from the shaft as needed for purposes of excavation. When the headings had been extended somewhat beyond the points B and D, more accurate droppings were made, the point C finally established, and the chord B C (produced) fixed by readings on brass scales at X and Y. To carry the line into the west heading the point a on the tangent produced was located by measurement from C; B was also fixed. At a, the required angle was turned and the tangent fixed by a reading on a scale fixed about 300 ft. further west. In the east heading an angle was turned at C and chord C D fixed by scale reading at Z. The point D was fixed by measurement from C. The point C on tangent produced was also located, the final angle turned, and the tangent fixed by reading on a scale fixed in the roof about 300 ft. east of C.

At the east portal in Central Park, near 110th St., no particular difficulties were encountered in carrying line into tunnel, except that it was necessary to use an offset line. At the shaft near Broadway, the difficulties were equally as great as at the Central Park West shaft, but as the distance to be driven was not great, so great accuracy was not required.

The brass scales used were fixed in the roof of the excavation, as shown by Fig. 87. The center portion of each bar was marked with a scale of tenths and hundredths, and from it was hung a sliding hanger with a vernier, whose zero was at a point on the continuation of the suspended plumb line. The vernier read to two-thousandths. Each vernier reading was preserved, so that by setting the vernier hanger to this recorded reading the original point could be had for reference at any time. The portion of the center line shown in Fig. 86, being accurately determined in the manner described, it was a simple matter to continue the tangents east and west. The method of fixing the center line which has been described was devised and carried out by Division Engineer Beverly R. Value and Assistant Engineer F. W. Carpenter.

MATERIALS PENETRATED.—The tunnel work of Section VII. was through mica-schist rock. This rock was for the most part tough and solid, and gave little trouble in its excavation. Comparatively little water was carried by the rock strata.

EXCAVATION.—The excavation of the tunnel was conducted from two shafts and one portal. The portal was located at the east end, just west of the main driveway in Central Park, where the high rock ridge falls abruptly to the general level of the driveway and the adjacent streets. This portal opening was begun on May 14, 1901. Fig. 88 shows the appearance of the portal excavation on July 23, 1901. The first excavation was, however, begun at the shaft located just within the park at 104th St., as already described. This shaft was 10 × 20 ft. in plan; work was begun sinking it on Dec. 21, 1900, and it reached sub-

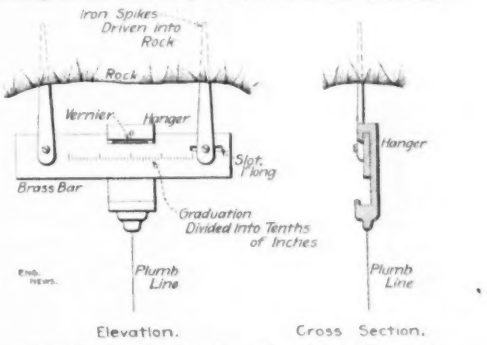


Fig. 87. Device for Marking Termini of Base Line in Central Park Tunnel.

grade at a depth of 60½ ft. on June 15, 1901. Fig. 89 shows the shaft head plant on Aug 28, 1901. The second shaft was located on private property, a house on 104th St., about 110 ft. east of Broadway, being torn down for the purpose. It was 45.8 ft. deep and 12 × 22 ft. in plan; work was begun Oct. 30, 1901. The distance from the Central Park portal to the Central Park shaft was 1,725 ft., and that from the Central Park shaft to the 104th St. shaft was 2,162 ft.

Excavation was begun in both directions from each shaft and westward from the portal. The method of taking out the rock was the single heading and bench system, common in American rock tunnel work. Fig. 90 shows the relative forms and dimensions of the heading and bench cuts. In working from the portal the bench was taken down quite close behind the heading, but at the shafts work was concentrated on the headings, it being the purpose of the contractors to open first a continuous heading through the

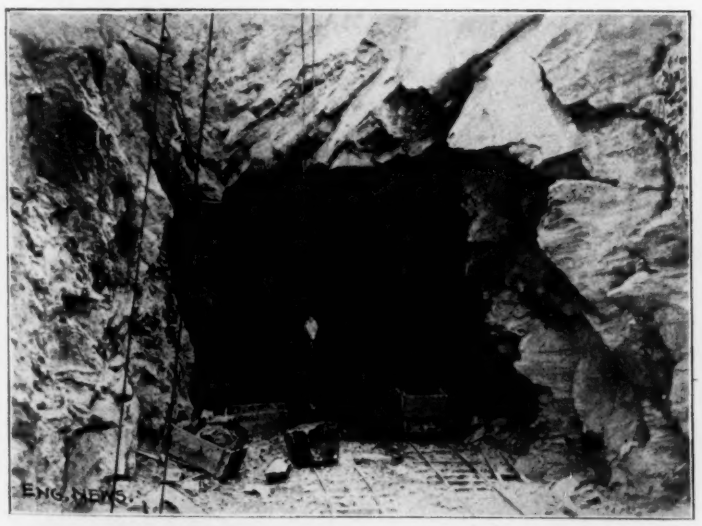


FIG. 88. VIEW OF PORTAL HEADING IN CENTRAL PARK TUNNEL.

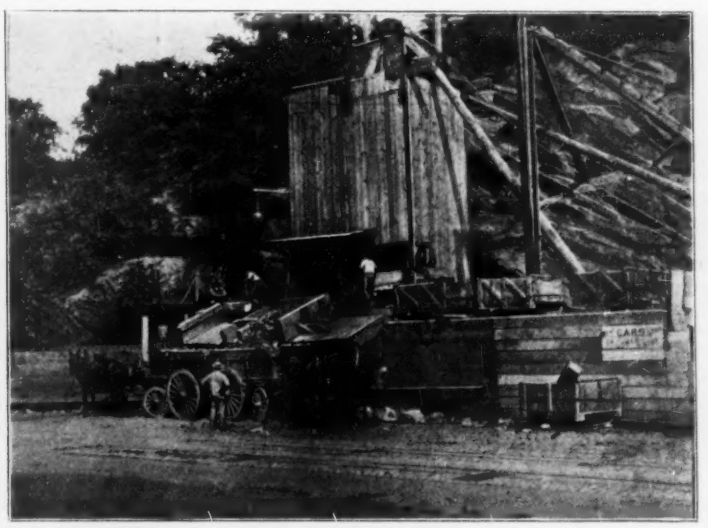


FIG. 89. SHAFT HEAD PLANT AT CENTRAL PARK SHAFT OF CENTRAL PARK TUNNEL.

tunnel for ventilation, and then to remove all of the bench through the east and north end of the tunnel.

To take out the heading a wedge-shaped cut was first made by drilling two vertical rows of four holes, one row on each side of the vertical axis. This center cut was then enlarged by drilling holes parallel with the tunnel and blowing in the sides of the wedge-shaped cut. Altogether from 22 to 36 holes were drilled in each face, using Ingersoll drills on columns, and they were fired in rounds of from four to seven holes with Forcite, containing 50% nitro-glycerine. Care was taken not to exceed the necessary limits of cross-section in making the main cut, it being considered cheaper to do considerable trimming of the sides than to do a large amount of back-filling. In each of the shaft headings two eight-hour shifts were worked each 24 hours, but in the portal heading only one shift was ordinarily worked.

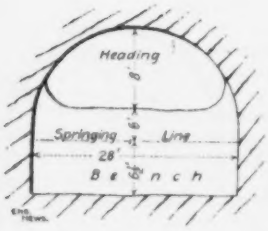


Fig. 90. Diagram Cross-Section, Showing Form and Dimensions of Heading and Bench.

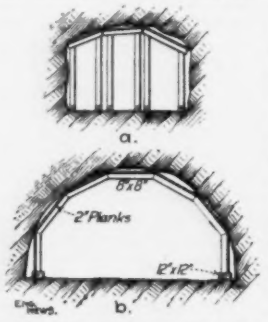


Fig. 91. Diagram Showing Method of Timbering Heading in Disintegrated Rock.

The general method of hauling the spoil from the working faces was the same in all headings. Mules were used to haul the cars on the up-grade trips and gravity runs were made on the down-grade trips. As previously noted, the grade of the tunnel floor was continuously a down-grade of about 1% from west to east, so that in the headings working eastward the loaded car trips were all up-grade while in the headings working westward the loaded car trips were all down-grade. The spoil tracks for the heading work were laid on the top of the bench and the cars took the shaft elevators at this level. After taking out the bench the guide timbers for the cages were lengthened. The shaft elevators lifted the cars to a scaffold 15 ft. above the street, where they were run onto tipples and dumped into chutes, which were emptied into wagons. At the two main shafts the elevators occupied the central portion of the shaft, thus leaving two end compartments open for ladders and pipes. A stiff-leg derrick only was used at the Broadway shaft, no elevators being used. A stiff-leg derrick was used at the Central Park shaft while the shaft was being sunk and after that was left standing to handle materials on the surface.

As previously stated, the bulk of the bench was removed from the east end of the tunnel. In view of this plan the heading and bench from the east portal were advanced nearly simultaneously, as already noted; also the open-cut work between the portal and 110th St. was hastened to completion so that a shaft-head plant could be erected at 110th St. through which the spoil could be raised. The depth of the bench to be taken out was about 12½ ft., as shown by Fig. 90. To break it down from four to six vertical holes about 6 ft. back of and parallel to the face were blasted. To remove the spoil two 36-in. gage tracks were laid on the bottom of the tunnel from the 110th St. shaft to the working face. These tracks were laid near the walls of the excavation and extended to the face of the bench. Between the narrow gage tracks was laid a stretch of standard gage track for a locomotive crane. This locomotive crane was one of those used on the subway trench north of 110th St., with the long boom replaced by one of wood only 12 ft. long, giving it a maximum capacity of seven tons. In operation this derrick was run close to the bench face and was used to lift the skips to and from the cars standing on the side tracks. The arrangement enabled a number of skips to be strung along the face on the tunnel floor, thus doing away with lost time waiting for skips and with the handling of the spoil by hand to the car level. The skips used were of 40 cu. ft. capacity. From the working face to the shaft the run of the loaded cars was by gravity, but the return trip of the empty cars was made by mule power.

TIMBERING.—In extending the west heading from the 104th St. shaft, disintegrated rock was encountered at two points, which required the use of timbering for a short distance to support the roof of the excavation. This was the only timbering required on the tunnel work, except for a short stretch east and west of the Broadway shaft. When timbering was required a heading about 10 ft. high and 18 ft. wide was first driven and strutted, as shown by Fig. 91a. When this heading had been driven some distance it was widened laterally so as to open the whole of the section from the springing line upward. Sills of 12 × 12-in. timber were then laid at the sides, and on them was erected 10 × 12-in. segmental timbers carrying plank lagging, as shown by Fig. 91b. These segmental arches were placed from 2 to 3 ft. apart, and were generally so located that the concrete lining could be built within them, they being left permanently in the work.

OPEN-CUT WORK.—From the Central Park portal north toward the end of the section the normal tunnel section was built some 100 ft. in open cut. Fig. 92 shows this work in progress, and gives a very clear idea of the centering used and the progress of the concrete lining. At the end of this tunnel section two-track steel subway construction began. All this work was done in open-cut excavation. To build the open-cut tunnel arch section a single wide trench was opened and the concrete lining was built in this trench on suitable centers. Fig. 93 is a view taken from just inside the portal heading, showing the standard subway construction completed south to about the point where the open-cut tunnel section of Fig. 92 joins with it. To handle the material in the open-cut work from the portal north to 110th St. a Lidgerwood cableway of 450-ft. span and 4 tons capacity was used. A view of this cableway spanning the trench in which the subway construction is progressing toward the tunnel portal is given by Fig. 94.

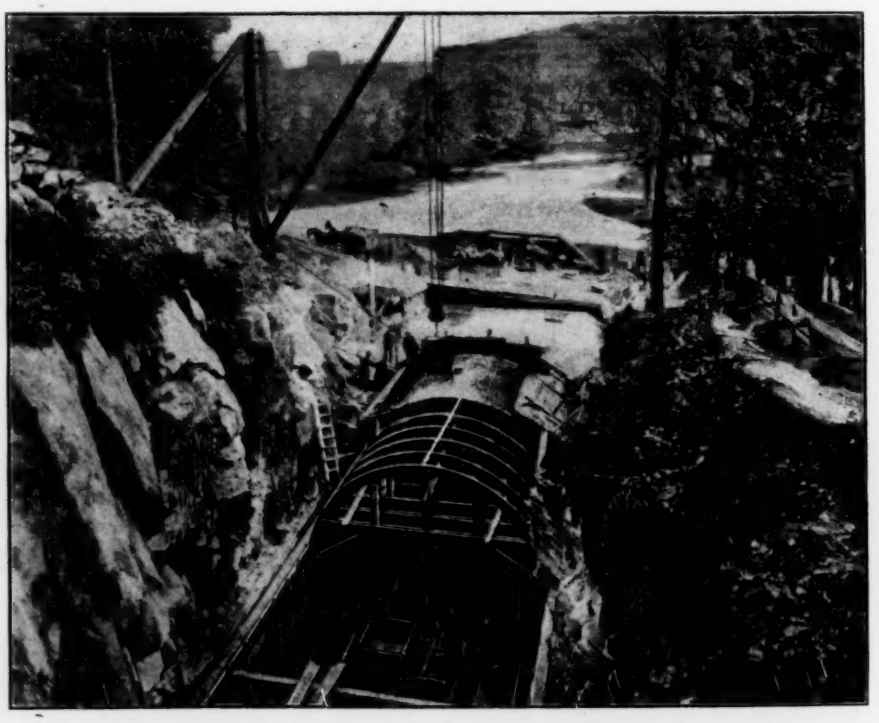


FIG. 92. VIEW SHOWING TUNNEL CONSTRUCTION IN OPEN CUT.

CONCRETE LINING.—As soon as the open-cut structure from 110th St. to the tunnel portal had been completed, it was possible to restore the original surface and remove all plant from the park by establishing a head-house and ca... at 110th St. and Lenox Ave., to take place of the portal opening. This shaft p... was made rather elaborate, since practic... all of the bench excavation and all of t... concrete lining work were carried on from ... A three-compartment timber elevator framew... was erected on the floor of the completed s... way and carried up through the subway r... to a suitable height above the street surface, as indicated by the progress view, Fig. 95. T... elevator cages occupied the two end compart... ments, while the center compartment w... left open. The elevator engine was placed at t... bottom of the center compartment on a timb... cribwork filled with concrete. The spoil cars r... ing on the cages were dumped into the loadi... chutes shown by Fig. 95, or into a bin at on... side whose top was at the level of the chutes, and whose bottom was on the street surface. Only such stone as was suitable for the crusher was dumped into this bin.

Just north of the head-frame a Gates stone crusher was set in the subway with the top of its hopper flush with the street, the machinery being below the surface. The open bottom of the stone bin was only a few feet away from the crusher hopper. North of the crusher a framework carrying elevated bins for crushed stone and sand was built. A bucket elevator ran from the discharge of the crusher to the stone bins, where the screens were placed, and a similar elevator ran from the street surface to the sand bin. Underneath the bins was placed a Hains concrete mixer, with its uppermost hoppers flush with the street and the discharge spout of its lowermost hopper just high enough above the subway floor to clear a skip mounted on a spoil car.

The general construction and the theory of operation of the Hains mixer were described in Engineering News of July 6, 1899. As constructed for the work here described, this mixer consisted of three rectangular hoppers filling a space between the roof beams of the subway. The chutes from these three hoppers discharged into a conical hopper beneath, and the center chute of this second hopper discharged into a third hopper of similar form beneath. The third hopper discharged into the skip of a spoil car. Sliding gates closed all the chutes. In operation cement, sand and broken stone in the proper proportions were placed in each rectangular hopper in the order named. The sand and broken stone were chuted

from the bins above. The chutes of these hoppers were then opened one after another, and their contents successively discharged into the conical hopper beneath, water being added from a tank above as each hopper was discharging. The second hopper was then discharged into the third, and that in turn into the concrete skip on the car beneath. The concrete was gaged rather wet and the mixing was rapidly performed. From the mixer the concrete-laden cars were hauled by mules to the points where the lining work was in progress.

To place the lining, side molds and centers mounted on traveling platforms were employed. These traveling platforms were operated in sets of two and a platform carried a derrick for handling the skip-loads of concrete. Fig. 96 shows the derrick platform partly assembled on the surface, and gives a fairly good notion of its general construction. Fig. 97 shows the center platform similarly assembled.

Structurally these platforms were quite simple, and a few dimensions, with the views given, will explain their construction sufficiently. The derrick platform consisted of two vertical side trusses braced together across their top chords by transverse timbers, from which a knee brace ran to each side post. The bottom chords of each truss consisted of two 4 × 12-in. timbers, held apart about 4½ ins. by the 6 × 12-in. posts which were set in and spaced 4 ft. apart c. to c.; the top chord was of 6 × 12-in. timber laid flat, and the diagonals were 4 × 8-in. timbers laid flat. There was also a ¾-in. tie rod at each post. The transverse timbers were 8 × 10 ins., and the knee braces 2 × 12 ins. Each truss had four panels and was thus about 18 ft. long. The platform carrying the centers was of exactly similar construction, except that it had six truss panels and was, therefore, 27 ft. long; was floored over with 2-in. plank, and that the floor beams were 3×12-in. timbers set on edge, and were tied together longitudinally of the platform by a 2 × 10-in. plank placed 5 ft. each side of the center line and beneath. These longitudinals enabled temporary struts to be inserted underneath the platform floor as an extra precaution to prevent deflection of the cross-braces under the weight of the centers and their loads of concrete arch. Each platform was mounted on wheels placed underneath the side

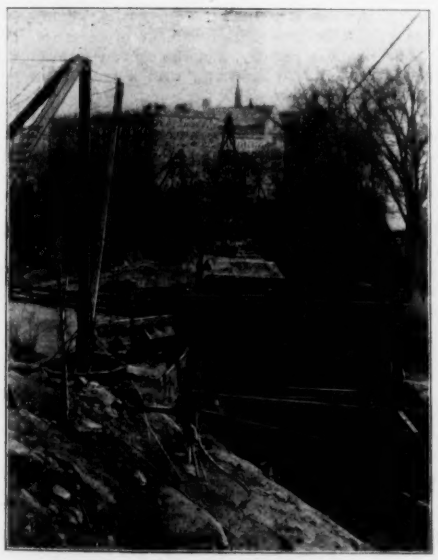


Fig. 94. View of Open Cut Subway Work at North End of Section VII.

trusses. These wheels were 12 ins. in diameter and had double-flanged 2½-in. faces or treads.

The height of the platform flooring above the base of rail was 7 ft. 5½ ins. The ribs for the arch centering were set up on this flooring 4 ft. 6 ins. apart, a rib being set over each post of the side trusses. These ribs were blocked up by wedges to secure the proper elevation. Fig. 97 shows one of the ribs erected. Each rib consisted of a bottom chord or tie, consisting of two 3 × 6-in. timbers and one 2 × 6-in. timber bolted together. The arch rib was made up of 5-ft. segments composed of three 2 × 10-in. planks bolted together. The center post was 4 × 6 ins., the lower knee braces were 4 × 6 ins., the horizontal chord tie consisted of two 3 × 4-in. timbers, and the radial brace from the intersection of the chord tie and the vertical post to the arch rib on each side of the center was 4 × 6 ins. These

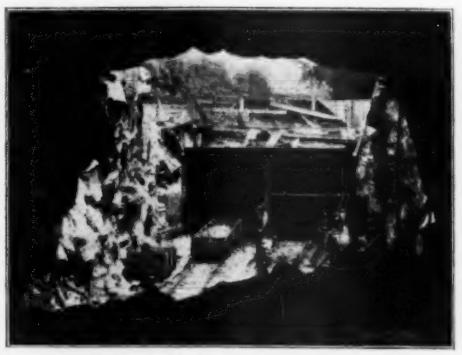


Fig. 93. View from Inside Portal Heading, Showing Beginning of Standard Subway Running North.

radial braces are not shown by Fig. 97, they being added to the design later. The lagging used with the centers was narrow 2¾ × 2¾-in. stuff. The construction of the forms for the sidewalls is shown by the sketch, Fig. 98. Outside of each side truss at each post was hinged a rib, A, by means of the timber, B, spiked to the transverse brace and the bolt, C. When the platform was in position these ribs were alined and fixed by inserting wedges in the slot, D. The lagging was then placed a few pieces at a time from the bottom and the concrete was filled in behind it. By removing the wedges and lagging the ribs were freed fom the sidewalls and the platform could be moved ahead.

The method of operating the traveling platforms was simple. The floor and sidewall footing courses of the tunnel lining were first laid. The tops of the footing courses rise above the floor level, and they also extend inward 2 ft. from the faces of the sidewalls. On the top of each footing, 16 ins. from the sidewalls, was laid a line of 80-lb. rails set accurately to line and grade and fastened to blocks previously set in the fresh concrete so as to serve as a basis for the adjustment of the sidewall forms and centers. The wheels of the traveling platforms ran on these rails. To build a section of lining the sidewall platform was first run into position and behind it and separated from it by an opening was set the derrick platform. The derrick boom commanded an opening between itself and the arch carriage which followed. Fig. 99 is a sketch diagram showing the arrangement of the platforms in plan. As will be seen, the side portions of the interval between the platforms were bridged over, but the center portion was left open. Tracks of 30-in. gage were laid along the bridges and extended over the molding platform.

The two platforms being set as described, the next step was to adjust the vertical ribs of the sidewall molds as previously described. A few of the lower lagging boards beginning at the bottom were placed and molding of the sidewalls was begun by shoveling concrete from the cars standing on the adjacent track on the tunnel floor. It should be noted here, perhaps, that the platforms had sufficient clearance underneath to allow the spoil tracks and cars to continue uninterrupted beneath them. The building of sidewalls was somewhat troublesome. First, two rows of 9 × 9-in. four-way vitrified electric ducts were set, one on top of another, 8 ins. back of the lagging boards. The first row of conduits rested on the wall footing. After these conduits had been placed and alined, the concrete was filled into the 8-in. space between them and the lagging, and also into the space between them and the wall of the excavation. The narrow quarters in which this work was done and the necessity for not disturbing the alinement of the ducts in tamping the concrete made the work difficult. The next two rows of conduits were then set and the filling completed to a level 6 ins. above the top of the top row, so as to give an anchor between the inside and outside walls of concrete, as indicated by Fig. 98. Finally, the uppermost three rows of conduits are set and the concrete filled in. Above these conduits the wall was solid concrete, and was carried up within the sidewall molds to a level where the roof arch centers begin.

The roof arch center ribs were all set at once, by wedging them up and adjusting to line and grade. Props were then placed under each cross-brace, over which there was a rib at points 5 ft. on each side of the longitudinal axis of the platform. The haunch lagging was then placed so as to continue the work done by the sidewall molds upward along the curve of the arch. The concrete cars were then run under the opening between the two platforms, their boxes were lifted by the platform derrick and set on cars standing on the platform bridges. These cars were run along the platform and their contents shoveled behind the arch lagging and tamped in place. As the filling progressed upward from each side additional lagging was placed until a narrow key opening only was left at the crown. This key portion was constructed by filling in from the end and by using lagging in 4½ ft. lengths to extend over two ribs only. As soon as the concrete was in place and had set the centers were lowered and the side molds freed from the walls, and the platforms pushed ahead for the construction of another length of lining. Two sets of traveling platforms were used, one working ahead of the other. As soon as the rear set had caught up with the lining completed by the set ahead it was run forward and substituted for the second set, while the second set was run ahead and started a new piece of work.

POWER PLANT.—Compressed air was used to run all drills, cableways, derricks and other machinery. This air was taken from a central power plant located on a vacant lot at 111th St., near Lenox Ave. The power plant consisted of a 30 × 30-ft. engine room and a 50 × 65-ft. boiler room. In the boiler room there were four 125-HP. return tubular boilers, using pea coal. These boilers were set two in a battery, with a stack for each battery. Steam was supplied, at 100 lbs. pressure,

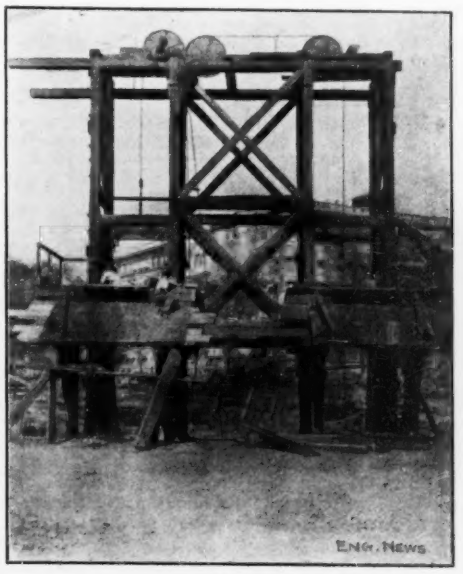


Fig. 95. View Showing Elevator Framework at 110th St. Lift.

to two 24 × 24½ × 30-in. straight-line Ingersoll-Sergeant air compressors, discharging into a 5½ × 18-ft. cylindrical receiver, in which about 90 lbs. pressure was carried. The jacket water was used for boiler feed and the exhaust discharge through the feed-water heater. Two 6 × 4 × 6-in. Worthington feed pumps supplied the water to the boilers.

From the receiver an 8-in. pipe ran to 110th St. From a point on 110th St., near Lenox Ave., a

line of 6-in. pipe ran to Central Park West shaft; here the pipe changed in size to 4 ins., and continued to the Broadway shaft. A 4-in. pipe was also laid along Lenox Ave. as far as 120th St. This Lenox Ave. line was, however, not in constant use, as steam was largely used.

The work of Section 7 was carried out under the direction of Mr. Beverly R. Value, Division Engineer of the Rapid Transit Commission; Mr. F. W. Carpenter, Senior Assistant Engineer; and Mr.

FIG. 96. VIEW OF PARTLY ERECTED TRAVELING DERRICK PLATFORM FOR CONCRETE LINING WORK.

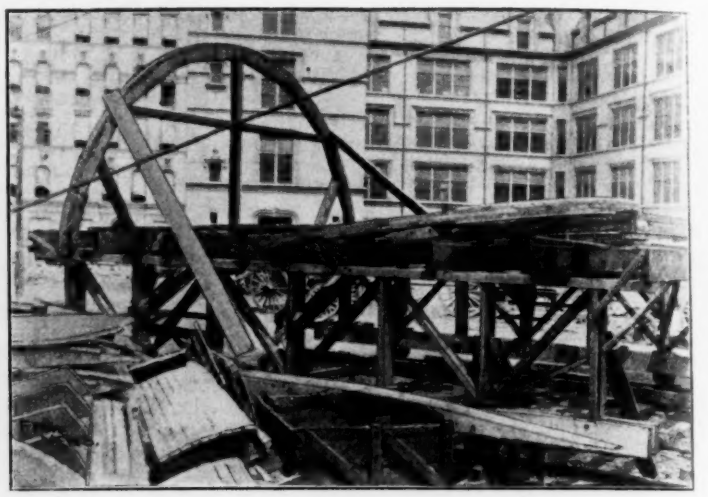


FIG. 97. VIEW OF PARTLY ERECTED TRAVELING CENTERS FOR CONCRETE LINING WORK.

George A. Taber, Assistant Engineer in immediate charge of the section. Mr. George Perrine, C. E., was Engineer for the Contractor.

THE NEW WORKS FOR THE BIOLOGICAL TREATMENT OF THE SEWAGE OF MANCHESTER, ENGLAND.

By J. P. Wilkinson.

The new works now contemplated and being carried out comprise the following:

(1) Five additional tanks, with contingent works, similar to the existing precipitation tanks at Davyhulme; (2) 46 acres (net) first-contact bacteria beds, in 92 beds of half an acre each, at Davyhulme; (3) 26 acres of storm-water filter beds, also at Davyhulme; (4) conduit for conveyance of first-contact effluent from Davyhulme to beds and land at Flixton; (5) 46 acres of (net) second-contact bacteria beds on land in the township of Flixton; and (6)

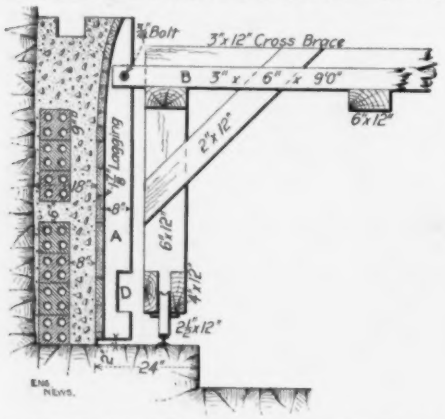


Fig. 98. Sketch Detail Showing Construction and Operation of Side-Wall Mold.

works of irrigation in Flixton and Carrington, covering approximately an area of 100 acres.

CAPACITY OF NEW WORKS.—The scheme under which these works are being carried out has been designed to deal with a maximum rate of flow equal to 151,000,000 gallons per 24 hours, the flow up to 75,500,000 gallons being treated by double contact on the bacteria beds and the subsequent 75,500,000 gallons on the 26 acres of storm-water filter beds. The excess of the sewage flow in time of rain beyond the maximum rate will be passed off into the Manchester Ship Canal at the Mode Wheel storm-water overflow.

SCREENING.—The present duplicate screening chambers will be continued in use as at present.

*Condensed from a paper before the recent meeting of the Sanitary Institute of Great Britain.

TANKS.

SIZE OF PRESENT TANKS.—The number of tanks at present existing is 11. Each of these is 300 ft. in length, 100 ft. in width, with an average depth of 6 ft., containing a volume of 1,350,000 gallons. Four of these existing tanks will be set aside as detritus tanks for storm water. In substitution for the four tanks set apart in connection with storm water, five new tanks will be provided.

ULTIMATE CAPACITY OF TANKS.—With these modifications and extensions the water capacity of the septic tanks will be 18,984,000 gallons, giving with the four storm-water tanks (which may probably be used for night flow) a total capacity of 24,384,000 gallons.*

BACTERIA BEDS, DAVYHULME.—The first contact beds are disposed on the land in three blocks or series, each series served by main supply channels 18 ft. and 16 ft. wide, with subsidiary channels 6 ft. and 5 ft. wide, as required in the several cases. The latter are constructed with draw-off or pick-up channels of the same width below, for economy of area and construction.

SUPPLY TO BEDS.—The supply to and discharge from each bed are radial, delivering from one center outwards over the surface and converging towards the same center by the under-drainage below. The sewage is admitted from the supply channel to a distributing reservoir, from which it flows over a sill or weir of circular form, and thence along channels cut in radiating form over the surface of the bacteria bed. These channels are lined with fine-grade material, which tends to arrest suspended matters on its surface and retain them from entering into the body of the bed.

DRAINAGE OF BEDS.—The under-drainage of each bed is also laid out in radial form, the drainage lines converging into a main collecting drain, which is concentric with the distributing weir, and which communicates at each end with manholes, or at the center with an outlet well, from which the discharges enter the draw-off channel. The under-drains are channels formed in the concrete bottom of the bed, covered with stoneware perforated slabs, set in rebates, so as to be flush with the surface of the bottom.

MATERIAL OF BEDS.—The average depth of the clinkers forming the body of the bacteria beds is 3 ft. 4 ins., each bed having a cross-fall of 2½ ins., and the space between the radial drainage lines being formed with a ridge in the center to facilitate the discharge of the final drainage at the bottom. The body of the bacteria beds is composed of furnace clinkers, from which the fine material has been removed by screening, and the coarsest material is used for covering, more particularly the radial drainage lines, and also the concrete bottom as far as practicable.

STORM-WATER FILTER BEDS.

These beds have been designed to deal with a maximum quantity of 75,500,000 gallons per 24 hours, covering an area of about 26 acres.

The general area of each filter bed is about 1 acre, and the beds are 2 ft. 6 ins. deep, being filled with unscreened clinkers, the coarser part of the material being selected for the covering of the under-drains and the surface of the bottom. These beds are at present being used as contact beds for the purification of chemical tank effluent, or for the treatment of storm water by continuous filtration. In the former case the bed is filled and discharged in a manner similar to that in use on the bacteria beds proper; and in the latter case provision is made for the ponding of the liquid upon the surface to a depth of about 6 ins., at which depth delivery commences over a [illegible] mouth pipe in the outlet well, continuing during the progress of the storm, the body of water in the bed being drawn off after the rain has ceased.

CAPACITY.—Under the latter conditions of working each acre of storm filter will receive about 435,600 gallons before discharge commences, and 26 acres will thus be adequate for the reception of about 11,400,000 gallons before commencing to flow off, after which the rate of discharge would be about 2,904,000 gallons per acre per day. The storm-water tanks and filters together will thus provide for the storage of a volume of 16,800,000 gallons in time of storm before discharge begins, covering a period of at least five hours' heavy rain, exclusive of the volume treated in bacteria beds.

SUPPLY CHANNELS.—In general there are two points of supply to each acre of area to which the under-drainage also is conducted. The floor of these beds is the natural ground surface, which is generally a clayey marl, covered with a layer of cement concrete where the character of the ground renders it necessary.

UNDER-DRAINS.—The smaller under-drains are of brick, laid with open joints on a concrete foundation, and covered with open-jointed stoneware or fireclay slabs cemented down, the main collecting drains being close jointed.

CONDUIT FOR FIRST-CONTACT EFFLUENT FROM DAVYHULME TO FLIXTON.

The volume of first-contact effluent to be conveyed is 75,500,000 gallons per day, and the conduit or channel is designed to be 13 ft. in width, with a gradient of 1 in 5,000, or 1.056 ft. per mile.

A route has been selected following approximately the course of the Ship Canal. For the principal portion of the route the channel is an open one, and where high ground intervenes the work will be carried out in open cutting and arched over. In the proposed channel a flow of 43,200,000 gallons per day represents a water depth of 2 ft., and with a water depth of 3 ft. 3 ins. it is calculated to discharge a volume of 87,600,000 gallons per day. In the former case the velocity would be 155 ft., and in the latter case 192 ft. per minute. There are no engineering difficulties along the route except the crossing under the

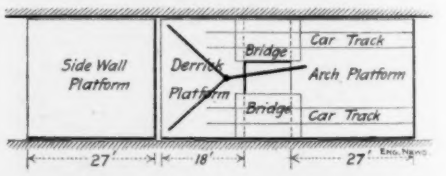


Fig. 99. Sketch Plan of Traveling Platforms in Position for Work.

Cheshire Lines Railway near the land at Flixton, which would be constructed in tunnel with brickwork of extra strength.

SECOND-CONTACT BACTERIA BEDS, FLIXTON.

AREA OF BACTERIA BEDS.—In accordance with the requirements of the Local Government Board, these will be 92 in number, 46 acres (net) in extent. They will form a compact range, four beds in width and 23 beds in length, with supply channel on the upper or north side and effluent discharge channel on the south side. The beds will be separated by distributing channels, with pick-up or draw-off channels below and cross-roadways between, as at Davyhulme. The method of supply and distribution is precisely the same as before described.

*The quantities have been converted to U. S. gallons throughout.

IRRIGATION AREA.—A total of about 100 acres is available for irrigation.

The main drains would lie midway between the carriers, communicating with an open channel delivering into the Ship Canal over a tumbling bay, placed sufficiently far back from the canal bank to minimize any current prejudicial to navigation. The under-drainage would be of agricultural drain pipes 3 ins. in diameter, laid out in herring-bone form, and at an average depth of 2 ft. (connecting, of course, with larger drains.—Ed.)

LAND AT CARRINGTON AND FLIXTON.

The gross area of the land for which compulsory powers of acquisition have been obtained is 204½ acres, exclusive of river bed, in addition to which small areas, amounting to 2½ acres, are suitable for acquisition to straighten the boundary, making a total area of 207 acres.

MATERIALS AND MANNER OF CONSTRUCTION.

TANKS.—For the enclosing walls and division walls of additional tanks and carriers and the submerged walls of the present and new tanks, the material will be common brick in cement mortar, faced with blue brick on both sides to the under side of the copings. The copings of tanks and carrier walls will be of hard Yorkshire stone, to harmonize with present work. The submerged walls will be finished with a coping of blue brick on edge, in cement, with bull-nosed angles. The bottoms of the new tanks will be of Portland cement concrete.

CHANNELS.—The work in all pick-up or draw-off channels and division walls is of Portland cement concrete, the tops being finished in the same material throughout. The concrete will be the predominant feature in the construction of the works.

LIGHTING.—Provision will be made for lighting the beds by electric lamps placed between each pair of outlet wells, where the sluices are situated.

COST.—The total cost of the new works, as above described, is $2,368,000.

PLACER GOLD DEPOSITS IN ALASKA.

Now that the excitement due to the early discoveries of gold in Alaska is over, we may look to see a great development of the Alaska gold fields by large companies whose operations will be directed by engineers of experience.

That gold-carrying gravel is to be found in great and paying quantities is beyond doubt, but transportation has been so expensive that only abnormally rich gravel could be made to pay. Mr. John D. McGilliway, a mining engineer, who has just returned after five years in Alaska, has given the following facts and opinions to the reporter of a New York daily paper:

The Yukon country is not appreciated by the outside world. There was too much excitement about the first discoveries, with the result that an abnormally large number of persons, who were unaccustomed to the country, rushed in. It is safe to say that nine-tenths of those who went north in the season of 1897-'98, came out disappointed. But they were not miners, or in other words, they were unfitted for that form of life. The miners who went in during those years are still there and doing well. Even now the number of miners from all of the Western states, who are going to that country, is continually on the increase.

Individuals without capital and working in a small way cannot make gravel pay, unless it yields more than $5 per cu. yd. Notwithstanding this, however, there are thousands of these parties who are making small fortunes.

This should suggest opportunities for capital, for there is an unlimited area of ground that is going to waste that can be worked at an expense not to exceed 25 cts. per cu. yd. All of the Yukon, from the Stewart River to Nome and south of the Yukon in the Kuskoquin and Copper River country, contains more high-grade gravel by far than will ever be found in the gravel gold fields now under development in other parts of the United States. The territory I speak of is more than 1,500 miles long by several hundred miles in width. The area of these gravels in the first place is very extensive and the gold values which they contain are higher on an average than were the gravels which were worked in California.

Naturally, you will ask why they are not being exploited. And the answer that usually occurs to persons not familiar with the North is that the climate is the greatest drawback. That, however, is not true, for we have a very good climate, plenty of water for hydraulic mining and the other requisites necessary for this form of development are as satisfactory as may be found elsewhere. The real reason, however, which has discouraged greater activity is the lack of transportation facilities. The cost of a sack of flour on the majority of the claims located in Alaska is $25, and of this $24 is for freight.

The Federal government has done good work in the way of geological surveys, but what is now of vital importance is the building of roads. An investment by the United States government of several million dollars in wagon roads from the Yukon to the different mining camps, would, in a few years, increase the gold output from the gravels from $5,000,000 to $25,000,000 per year. In addition to building wagon roads, I know of nothing better that the government can do for Alaska, than to encourage the building of a railroad from Valdez or other point south of the Aleutian Archipelago to the Yukon and center of Alaska. The copper discoveries, which extend all the way from the White Horse to the head of the Kuskoquim, will be sufficient inducement for capital to undertake the project.

In this connection it may be noted that five engineering parties sent to make the preliminary survey for the Alaska Central R. R. have recently returned to Seattle. The following general outline of the work is taken from a Seattle daily paper:

Col. C. M. Anderson, chief engineer, believes this work will commence in April of next year, and if rushed to a completion, the last spike will be driven two years later. The route for the road is from Resurrection Bay, across Turnagain Arm and Knik Arm, up the Susitna River Valley and Chulitna Valley, through Broad Pass, 25 miles east of Mount McKinley, down the Cantwell River to the Tanana and across to the Yukon at Rampart.

It is claimed by engineers of the road that the maximum grade will be less than 1%. In approaching the summit, which will be crossed at an altitude of 2,100 ft., the road has 90 miles in which to rise 1,700 ft.

There are four places where rock work will be necessary, from three to five miles in extent. In general Colonel Anderson claims the construction of the road involves no problem more serious than to build a road in the White River Valley, and in explanation says the line will traverse a system of north and south valleys, with occasional hilly interruptions.

Thirty-five miles of the road have been definitely located by the party under J. G. Scurry. The maps for the entire preliminary survey are now in course of preparation and will probably be completed in December. This will enable us to begin construction work about April. The route is all that could be expected, and when the line is completed a country rich in minerals, timber and agricultural resources will be opened. There are miles of rolling prairie that will make a fine agricultural region. Our pack horses this year picked their own food from these grasses.

The engineers in charge of the work who returned on the "Santa Ana" and "Bertha" are: J. G. Scurry, George S. Kopp, J. F. Blakely and W. T. Chalk.

COST OF TUNNELING AND MINING BY THE "HOLE CONTRACT SYSTEM."

Wherever men can be worked by the "piecework" or "stint" system universal experience has proven that not only does the employer get more work done for each dollar expended, but the workers themselves earn more money per day worked.

The main reason for this rather paradoxical condition is that, working under bosses, men are inclined to do as little as the boss will permit them to do without discharging them. The longer a job lasts under a given boss, the more does familiarity breed contempt for the boss, and lenience on his part for the men under him; for few men—even among bosses who are supposed to be minus a heart—care to be regarded as in any way resembling slave drivers, and the better they get acquainted with the men under them the more lenient do they become.

Engineers or contractors on jobs long drawn out can confirm the statement that where the labor is such as to involve no great skill the efficiency of men on long jobs is much less than on short jobs.

Making each laborer a contractor himself effects a remarkable change in his attitude toward his work. In the first place he becomes his own boss to a very large degree, the old boss becoming a superintendent who directs his work instead of a driver of men. This condition also incites the man to do his best, because the more work he does the more he earns. A prize for effective and hard work is always before his eyes, and what was before mere labor now becomes a muscular contest, a game with a goal to be won and honors for the winner.

True it is that many laborers are too lazy or too dull to be improved by any method, but that the vast majority of American workmen are intelligent and ambitious is shown by just such results of actual trial as we are about to give.

Unfortunately in many classes of work it is practically impossible to measure the work done by each man or each gang of two to four men, and where this is the case the contract or piecework system is difficult of application.

Here, however, is a chance for the ability of the foreman or manager to show itself. A little thought will often develop a scheme for adopting piecework that seemed not to exist before.

An illustration of the last statement was given in a paper entitled "The Operation of the 'Hole Contract System' in the Center Star and War Eagle Mines, Rossland, B. C.," by Carl R. Davis, E. M., read before the American Institute of Mining Engineers some time ago.

The mines in question contained a vein material that was exceedingly variable in hardness and in width of deposit, so much so that it was not practicable to measure the progress of a gang of miners by the linear foot of heading or stope. An attempt was made to keep account of the progress of each gang by counting the car loads of ore sent out, but this had to be abandoned because of the impracticability of keeping separate the ore broken by each gang, since the ore broken by several gangs of men was drawn off through the same loading chute in the mine. Finally Mr. Davis, having observed that the number of feet of hole drilled (by two miners) with a power drill did not vary 5% from month to month (although it varied greatly from day to day), decided to introduce a system of paying the miners according to the number of feet of hole drilled each day. The drillers worked in two 8-hour shifts, two men to a shift, the four miners thus forming a contract gang. Verbal contracts were made each month with each gang as to price per foot drilled. No charge was made for repairs to tools. A blasting crew of a few picked men worked from 1 a. m. to 7 a. m. while no other miners were at work, thus avoiding delays due to smoke accumulations.

Under the old wage system the miners received $3.50 a day, while under the new "hole contract system" they earn $4 to $4.25 a day, and the cost of stoping out ore is about 48 cts. per ton now, as compared with 86 cts. under the old wage system!

The following tables give details of cost:

Comparative Cost of Stoping Ore.

	System— Contract (49,849 tons mined), per ton.	Wage (13,818 tons) per ton.
Drilling	$0.356	$0.750
Blasting	.021	
Explosives	.100	.115
Total per ton	$0.477	$0.865

Cost of Driving Headings.

	Per lin. ft—	
Drilling	$5.36	$8.36
Blasting	.68	
Explosives	2.75	2.78
Total per lin. ft.	$8.79	$11.14

Four miners in drifting and cross-cutting average per month of 30 days a progress of 97.5 lin. ft. under the contract system, as against 50.8 lin. ft. under the wage system. Twelve men (3 shifts) shaft sinking averaged per month 58 lin. ft. under the contract system, as against 27.2 lin. ft. under the wage system.

It will be seen that the introduction of the contract system almost exactly doubled the efficiency of the men, whether they worked at stoping, drifting or sinking, while at the same time their daily pay was increased about 20%.

The figures are eloquent enough without further comments on the advantage of the contract system both to the miners and to the mine operators.

REMARKS ON THE NEW DESIGNS OF NAVAL VESSELS.*

By Rear-Admiral Francis T. Bowles.†

In the preparation of the recent designs for the battleships of the "Connecticut" class and the armored cruisers of the "Tennessee" class, consideration has been given to matters affecting the time required for completion. Up to the present ten battleships for the navy have been built and completed by contractors, and the average time required from the date of the contract until the date of the first commission has been four years and eight months, varying from a minimum of four years and one month to a maximum of five years and eight months. These periods are too great and disadvantageous both to the government and to the contractor, as the government fails to obtain the use of its property, and the cost of construction is undoubtedly increased. The causes of the delays which have occurred in the construction of naval vessels are numer-

*Abstract of a paper read at the tenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, Nov. 20 and 21, 1902.

†Chief Constructor, U. S. Navy, Washington, D. C.

ous and need not be recited here. The one conspicuous cause which it was possible for the government to remedy has been taken in hand in these designs and it is hoped eliminated. The contract plans now issued to the contractor, as shown in the annexed list, are very complete so far as all general features of the structure and arrangements of the vessel are concerned. The specifications have been arranged in a logical order, and have been made in all particulars definite and conclusive, instead of leaving many items of importance to the vessel and involving a large element of cost to the discretion of the superintending naval constructor, or "as may be required."

The steel structure is composed wholly of plates and shapes of commercial sizes. All shapes which have heretofore been used for naval vessels only have been discarded, having in view not only cheapening the cost of construction, but obtaining prompt deliveries of steel; the latter being a result never attained in practice when special shapes and small quantities are demanded. The number of structural shapes in the battleships has been reduced to 24, each size of angle bar being counted as a separate shape. Channel bars are used for beams and bulkhead stiffeners.

The contract period of construction for the battleships and armored cruisers has been placed at 42 months. It is believed that the complete and accurate state in which the plans and specifications have been issued is equivalent to a gain of six months over the time required to complete preceding vessels, and that there is a fair prospect of securing the completion of these vessels within the contract period, a result which has never yet been attained.

There are a number of special features, and some entirely novel ones contains in these designs affecting their military value; and while criticism of the society on any features which are obvious is expected and desired, it does not appear to be in the interests of the government that they should be discussed or explained in this paper.

The increase in size of naval vessels, which has been common to all navies in recent years and coincident with the increase in size of vessels in the merchant service, has been a subject of remark, and is a matter that will bear some careful consideration. Increase in size may be expected to involve decrease in handiness, but it does not necessarily do so; it does, however, practically always involve increase in cost.

The problem of the naval architects should be to produce the best military unit for the least amount of money, and it remains for those who command naval vessels to say what limit of military power shall be placed upon the individual unit of the fleet. A distinguished foreigner recently asked why our battleships were so large, or of so great displacement, and was told in answer that the conditions of our service seemed to make it necessary for our battleships to go anywhere and be ready to fight when they get there. While our recent battleships are undoubtedly large, the "Virginia" class of five vessels being 14,980 tons normal displacement, and the "Connecticut" class 16,000 tons normal displacement, there are unquestionably great advantages obtained in the individual power of the battleship, as compared with its smaller predecessors. On the other hand, it is undoubtedly well for naval officers to consider whether the necessary military power could not be secured with about the same battery and armor protection, but less speed and coal capacity.

It should not be forgotten, too, that our naval designers are handicapped when it comes to very large ships by restrictions of draft more severe than those of many foreign powers.

In making comparisons to show the advantages of increase in size, they should be made between ships which are tactically comparable, that is, of practically the same speed and whose motive power and battery are of substantially equally modern design. In comparison in figures and percentages easy of comprehension, to show the effect of the increase in size of our own battleships, can be made between the "Alabama" and " Maine" classes (our most recently completed classes) considered together as being practically about 12,000 tons displacement, and the "Connecticut" class of 16,000 tons. The cost of the "Maine" and "Alabama" classes, complete, is about $6,000,000 each. The cost of the "Connecticut" class is about $7,500,000 each. The displacement has been increased 33% in passing from the " Maine" and "Alabama" to the "Connecticut." The cost of four "Connecticuts" will equal the cost of five "Maines" and "Alabamas." The weight devoted to battery and ammunition in the "Maine" and "Alabama" is 1,003 tons, and in the "Connecticut" 1,340 tons. Therefore, by increasing the displacement of the "Maine" and "Alabama" by 33%, there has been a corresponding increase in the weight of armament carried. The weight of the discharge of one round from all the guns of the "Maine" and "Alabama," above 6-pdrs., is 5,312 lbs., whereas the weight of the discharge of one round from all guns above 6-pdrs. on the "Connecticut" is 7,856 lbs.,or an increase of 47.9%. Therefore, for an increase of one-third in size there has been a gain of nearly one-half in effective battery power. Thus, if the battery power of the "Maine" and "Alabama" be considered unity, that of the "Connecticut" will be 1½; and for $30,000,000 four "Connecticuts" can be built, with a battery power of six, and five "Maines" and "Alabamas," with a battery power of five. In the case of the "Maine" and "Alabama" the weight devoted to armor protection amounted to 2,770 tons, and on the "Connecticut" to 3,992 tons, thus showing an increase in protection of 44% for an increase in size of 33%.

These illustrations of the enormous gain in offensive and defensive power of these vessels, corresponding to the increase in size, are well-known parallels of the greater cargo efficiency of the larger vessels in the merchant service, which is due to the fact that the larger vessel requires a less proportion of hull and machinery weights than the smaller for the same results in strength and speed.

If similar comparisons were made of the "Connecticut" with the "Oregon" class, there would appear an increase in displacement of 55%, an increase in the weight of armament and ammunition of 56%, an increase in protection of 36%, but an increase in the weight of battery discharge per round of only 10½%. But these comparisons are of little force on account of the low speed of the "Oregon," the inefficient gun mountings as compared with that of more modern vessels, and the inadequate armor protection. It should be remarked that the arrangement of the battery of the "Oregon" class is probably unsurpassed, and that it has furnished a type followed by other designers than our own.

A similar comparison with the "Kearsarge" and "Kentucky," larger vessels of practically 12,000 tons displacement, shows an increase of 14% in the weight of armament and ammunition, 34% in protection, and 20% in the weight of discharge of battery per round. The "Kearsarge" is an excellent illustration of what can be accomplished in large battery power, moderate speed (16 knots), and small coal supply. Discussions of the "Kearsarge" and "Kentucky," based upon normal displacement are, however, somewhat misleading, owing to the fact that certain circumstances of their design necessitated reducing the coal carried on normal draft to 410 tons.

The advantages of the increase in size and length of the "Connecticut" are clearly shown with reference to the elements of speed and power. Model basin trials show that at a speed of 18 knots the power required for the "Connecticut" is about 6% less than that required for the "Maine"; whereas, at 19 knots the power required for the "Connecticut" is nearly 50% less than that for the "Maine."

The normal displacement of the "Tennessee" class is 14,500 tons, an increase of 6% over that of the "Pennsylvania" class of six vessels now building of 13,680 tons. Certain features of the new designs have permitted this increase to be almost wholly devoted to armament and armor, thereby producing, at slight additional cost, very much greater military power. The addition to the weight of guns and ammunition carried amounts to 29.7% over that on the "Pennsylvania" class, and produces an increase in the weight of one discharge of the battery, amounting to 47.4%. The increase in the weight of protection carried amounts to 30% of that on the "Pennsylvania" class, and is devoted to an increase in the armor on the turrets and the redoubts of the 10-in. guns, which replace the 8-in. guns in the forward and after turrets on the "Pennsylvania" class, and to an increased area of side armor, affording ample protection to the magazines and the supply of ammunition to all guns, and also to a complete subdivision of the main battery by armor bulkheads.

The estimated speed of the "Tennessee" class is 22 knots, the same as the designed speed of the nine cruisers now building of the "Pennsylvania" and "St. Louis" classes, and will be effected without an increase in machinery weights.

These vessels will be exceeded about a knot in speed by a few foreign armored cruisers, but if their designs had been made upon the prime requisite of speed superior to all vessels of this category, it would have been necessary to sacrifice the battery and protection now assigned which enables them to present a heavy preponderance of battle power over any armored cruisers yet designed elsewhere, and also enables them to deal on occasion with a large proportion of existing battleships.

THE DEMOLITION OF A 150-FT. BRICK CHIMNEY BY DYNAMITE.

By W. J. Douglas.*

The accompanying illustrations show the means recently adopted at Washington, D. C., to demolish a brick chimney 150 ft. high. The chimney, Fig. 1, which was demolished, as described below, was located on the site of the proposed New District Building, between D and E streets and 14th and 13½ streets, N. W., Washington, D. C. The work was executed by Mr. Harry O. Brown, subcontractor for Contractor Jas. L. Carrick, under the direction of Col. John Biddle, Engineer Commissioner, District of Columbia, and Capt. H. C. Newcomer, Assistant to the Engineer Commissioner.

*Engineer of Bridges, Office of Engineer Commissioner, Washington, D. C.

The chimney was built of hard burnt red brick laid in natural cement mortar, in the proportion of about one cement to three sand, and was lined with fire brick also laid in natural cement mortar. An air space separated the chimney proper from the lining. Portland cement mortar was used for a few feet above the foundation, and sparingly throughout the stack, but was used so infrequently to be of value. The height of the chimney above the foundation was 150 ft. The diameter of the opening at the base was 7 ft., that at the top was also 7 ft. The bottom of the stack was 15 ft. square, up to a point 33 ft. above the foundation, where it changed to an octagon. The thickness of the outer wall at the base was 34 ins.; the thickness of the outer wall at the top, 13 ins.; and the thickness of the inner circular lining wall at the base, 13 ins. The inside lining stopped at a point 100 ft. above the foundation terminating in a 4½-in. wall. Fifty feet of the chimney were removed by pick and bar before resorting to dynamite, thus reducing the height of the stack to 100 ft. This was done on account of the feeling prevalent among the surrounding property-owners that their buildings would be endangered by throwing down the stack in its entirety.

After the stack had been reduced to 100 ft. a test blast hole was drilled into the northwest corner of the stack about 3 ft. above the foundation, on a level, and on an angle of about 45° with the north face, as indicated upon the appended sketch, Fig. 2. This hole was loaded with one dynamite cartridge (all dynamite referred to in this report was 40% Star brand), and fired without even cracking the wall. A second hole similarly located, and just 1 ft. above the first one, was then drilled and loaded with five sticks or cartridges and fired, loosening about one-third of a cubic yard of brick, which was easily barred out. Then shots of two and three sticks were made until all of the north wall for a height of 3 ft. had been removed excepting about 5 ft. at the east end. In the east wall of the stack there was a furnace opening 6 ft. wide, so that by the excavation of the north wall just described there now remained only a pillar 5 ft. long and 34 ins. thick carrying a large portion of weight of the east and north walls, as indicated by the sketch, Fig. 3. Then about 5 ft. of the fire brick lining was barred out as is shown on the aforementioned sketch. This lining was barred out for a height of 1 ft.

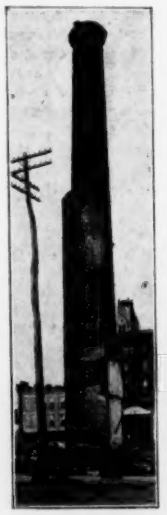


Fig. 1. General View of 150-ft. Brick Chimney at Washington, D. C., Just Before Demolition.

Fig. 4. View of Falling Chimney just after Firing of Blast, Showing Breaks.

The chimney was now in shape to be blasted down. Two holes were drilled into the 5-ft. pillar from the back on a dip of 45°, with the horizontal as marked at A on Fig. 3, and each hole was loaded with six sticks of dynamite. Then a hole was drilled into the west face at B, on a dip of

10° and on an angle of 45° with the west face and about 5 ft. from its end. Five sticks of dynamite were placed at X and five sticks at Y, in order to tear out the lining. This was not thought essential, but its use probably allowed the stack to fall further from the base, giving the contractor a better chance to handle the material in the demolished structure. These sticks at X and Y were laid between the outer and inner walls

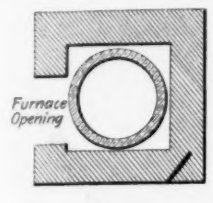


Fig. 2.

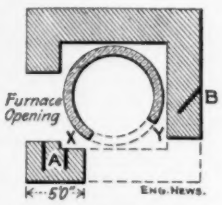


Fig. 3.

Figs. 2 and 3. Diagrams Showing Arrangement of Dynamite Blasts for Demolition of 150-ft. Chimney.

and covered with clay. Two exploders were placed in each hole in order to make sure of the blast and the 25 sticks located as described were fired at one time by a battery. Before blasting the chimney was carefully planked on the east, north and west faces; 2-in. and 3-in. × 12-in. × 16-ft. planks were used. Single planking was used on the west face, and double planking was used on the north and east sides. At the northeast corner and for 5 ft. on either side 6-in. × 12-in. × 12-ft. timbers were used instead of one of the thicknesses of planking. When the charge was fired the planking was found sufficient to keep the debris, resulting directly from the blast, from flying over 100 ft. from the chimney.

After the blast the stack immediately toppled over toward the north. The motion was slow and steady until a point about 20° from the vertical was reached, in which position it sheared into three sections, as indicated upon the photograph, Fig. 4, taken by a representative of the "Star," and fell rapidly to the ground. The approximate location of the stack in relation to the building and curb lines is indicated by the accompanying sketch, Fig. 5. This sketch shows that the end of the stack fell 20 ft. east of north, and that the furthest brick struck 140 ft. from the center of the base and 15 ft. back of the rear of the E St. sidewalk. About 60,000 bricks were completely separated from each other by the jar; these bricks were almost free of mortar. The mortar was not much stronger than first-class lime mortar. The area which was covered by the stack after the fall is shown on Fig. 5, by the irregular heavy full-lines. The outside dotted irregular line shows

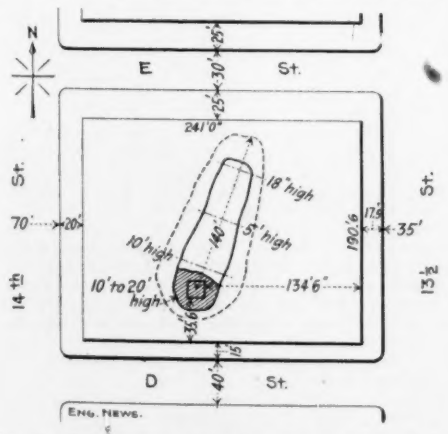


Fig. 5. Sketch Plan Showing Areas Covered by Debris and Scattered Bricks.

the limit outside of which no bricks were thrown. The area between the full line and the dotted one, aforementioned, was partially covered with scattered brick.

All brick excepting those included within the cross-hatched area were loose and practically free of mortar. The bricks in this area were in masonry blocks varying in size between 2 × 2 × 2 ft. and 3 × 6 × 12 ft., and averaging 3 × 3 × 6 ft. The bricks in these blocks were separated from each other by means of wedges and picks. The use of dynamite for this work was thought both dangerous and uneconomical on account of the damage to the individual bricks. The bricks were readily removed by means of wedges. Old whole bricks are at present worth, exclusive of haul, about $4.50 per thousand, and bats are worth about 40 cts. per cu. yd. It is thought that the stack was demolished with a profit to the contractor. The following is an approximate cost of the work:

Removing first 50 ft. with pick and bar.....	$150.00
Dynamiting stack	60.00
Cleaning new brick, 116,000 at 60 cts.....	69.60
	$279.60
Incidentals, 25%	69.90
Total	$349.50

On the credit side we have:

118,000 whole brick removed, estimated to be worth when cleaned	$531
About 240 cu.yds. old brick sold, worth it is thought at about 40 cts. per cu. yd.....	96
Total	$627

The estimated number of bricks in the stack was 140,000 red brick and 14,000 fire brick. These are accounted for, as follows: 116,000 whole red brick removed; 2,000 whole fire brick removed; 24,000 bats removed; 12,000 bricks not of any use; total, 154,000. The work of demolition was carried on under the supervision of Mr. Lapham and the writer.

THE DEVELOPMENT OF MODERN ORDNANCE AND ARMOR IN THE UNITED STATES.*

By Rear-Admiral Charles O'Neil, U. S. N.†

(*Concluded from p. 453.*)

POWDERS.

While the gun itself has been developed in a marked degree, its improved ballistics are no less due to the development of the explosives used as propellants, and while it is not intended in this paper to go into a lengthy discussion of the powders now and formerly used, it will not be out of place to refer briefly to them.

Black gunpowder, the oldest of all our explosives, originated in the far East, being used by the Chinese in making fireworks in the seventh century, although the place and date of its origin and the name of its inventor are unknown. The secret of its manufacture was carried by Arab traders to Bagdad, where its adaptability for war purposes was discovered. The army of Genghis Khan first used it in cannon in China in 1234, and the Chinese thus learned its military value.

It is generally accepted that it was used at the battle of Crecy in 1346. Western nations probably got their knowledge of it from the Arabs, nothwithstanding the stories of its invention by Roger Bacon and Schwartz, a German monk.

Black gunpowder is a mixture of 75 parts of saltpeter or potassium nitrate, 15 parts of charcoal, and 10 parts of sulphur. Powder made exactly from the same materials, mixed in the same proportions, differs greatly in its rate of burning, depending chiefly upon its physical properties, namely, density, hardness, shape, and size of grain, and the amount of glazing imparted to it. These facts have been known for many years and have been made use of for the purpose of adapting black gunpowder to guns of different class and caliber, within the range of its possibilities. Its use for military purposes is now greatly restricted, it being practically used only for filling shell, and as an igniting charge for brown and smokeless powders.

About the year 1883 a modification was made in Germany in the manufacture of gunpowder, and a material called "brown" or "cocoa" powder was produced, so called on account of its color. This powder is composed of 79 parts of saltpeter, 18 parts of charcoal, and 3 parts of sulphur. The charcoal is made from straw carburized in a special manner, and it is this under-burned straw charcoal which gives this powder its pecular color. It is pressed into hexagonal prisms, and has the property of producing high velocities with comparatively low pressures, adapting it for use in high-powered guns. It has, however, the disadvantage of giving off about 57% of the products of its combustion in the form of smoke and residue, fouling the bore of the gun and obscuring the vision. It is slow-burning as compared with black gunpowder, and requires a priming charge of fine-grain black powder to ignite it properly. It was, however, a great step in advance, and without it it would have been impossible to obtain the high velocities which immediately preceded the higher ones now obtained with smokeless powder.

*Abstract of a paper read at the tenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, Nov. 20 and 21, 1902.

†Chief of the Bureau of Ordnance, U. S. N., Washington, D. C.

Its cost was about 30 cts. a lb., and the average weight of a charge of it was one-half the weight of the projectile; thus a 13-in. gun firing an 1,100-lb. projectile would require a charge of 550 lbs. of brown powder.

Although the production of a satisfactory smokeless powder is a very recent event, the first discoveries in this line date back to the early part of the last century. The word powder is a misnomer as now applied to modern explosives used as propellants, as they are no longer used in powdered form except for small arm ammunition. Such explosives are now used in the form of rods, flat strips, perforated cylinders, and hexagonal prisms, and might be used in many other forms.

While smokeless powder of various compositions has been in use in foreign navies to some extent during the past ten years, its introduction into the United States Navy is of comparatively recent date, the first United States vessel to be fully equipped with such an explosive being the "Marblehead," in October, 1897. The next vessel was the "Newark," which was soon after placed in commission, and after her all the new ships as they were completed received an outfit of smokeless powder, as have also all ships coming up for extensive repairs.

Guncotton forms the base of our smokeless powder, which for want of a better name we call pyro-cellulose, "pyro" being the Greek word for fire and "cellulose" indicating the material of which the powder is made; that is, cotton, which is the form of cellulose best adapted for the purpose. When cotton is dipped in a mixture of nitric and sulphuric acid, washed and dried, it is changed in chemical composition while retaining its original form and appearance. It is, however, converted into a highly combustible explosive substance called "guncotton," which is capable of solution in various liquids. This latter fact is taken advantage of to convert the guncotton from a fibrous mass into a homogeneous body, designated from its glue-like consistency as "colloid."

It took about 50 years from the time of the first discovery of guncotton to ascertain that such a colloid possessed the remarkable property of burning progressively under pressure; that is, if formed into regular shapes or grains made up into charges and fired from a gun, the partially consumed fragments blown from the muzzle would retain their original forms in reduced dimensions; and while guncotton itself in its natural state cannot be used in guns as a propellant, being too quick and violent in its action and subject to detonation, it forms, when made into a colloid, a comparatively slow and progressively burning explosive which cannot be detonated, at least as far as we know.

What the new powder has accomplished may be illustrated by a single example. Within the safety limit of cannon constructed for an internal chamber pressure of 15 tons per sq. in., projectiles were formerly propelled with brown powder at a muzzle velocity of about 2,000 ft. per sec. To-day for the same strain they are propelled from the same guns at a velocity of 2,700 ft. As energy is proportional to the square of the velocity we find that a projectile moving at 2,700 ft. a sec. possesses an energy greater than one moving at 2,000 ft. a second, in the ratio of 2,700 squared to 2,000 squared, or as 7.3 is to 4; that is, the new powder has nearly doubled the power or energy to be developed from any given gun, with a considerable less weight of charge. If the same weight of charge was used the ratio would be fairly expressed by 2.5 to 1.

The composition and process of manufacture of all navy smokeless powder is the same, but a special size or grain must be made for each caliber of gun, and it can be used with safety for that caliber only. If the grain is too small the powder will be too quick and will get up too high a pressure in the chamber of the gun. If the grain is too large the powder will be too slow, and while the chamber pressure may be relatively low the maximum pressure will be developed further towards the muzzle of the gun, where it is weaker, to such an extent as to endanger the muzzle of the gun.

When guncotton is dissolved in a mixture of ether and alcohol it becomes a plastic mass, and in that condition is forced through dies to give it the desired form. The solvent evaporates rapidly, and the powder soon becomes hard like a piece of stone, but it takes from six to eight weeks to get rid of the solvent to the required extent, though by a process of so-called water-drying the time is greatly reduced.

The Russian and French smokeless powders are very similar in composition to ours, but they use it in flat strips only, while we use ours in the form of short perforated cylinders. The British use a powder made of 58 parts of nitro-glycerine, 37 parts of guncotton and 5 parts of vaseline, which is called "cordite," because it is made in the form of cords or rods. It is in many respects an excellent explosive, much more powerful than our powder, and requires only about one-half the weight of charge for a given gun as compared with ours, but it is very destructive to the bores of the guns, on account of the great heat evolved during combustion.

All smokeless powders, being slow-burning, require a small charge of fine-grained black, or some other quick-burning powder to properly ignite them. This priming charge is attached to the cartridge, and when the latter

is inserted in the gun the priming charge is next the primer.

The smokeless powder now used in the United States by both the army and navy was developed at the United States Naval Torpedo Station under the direction of the bureau of ordnance of the navy.

PROJECTILES.

The improvement of the gun and the building of armored vessels rendered it necessary that a corresponding improvement should be made in the quality of the projectile, as the vital parts of modern armored vessels are impervious to attack by cast-iron shot or shell.

In order to perforate armor great hardness and tenacity are necessary and in consequence the steel armor-piercing projectile was called into existence.

When the manufacture of high-power rifled guns was begun in the United States no establishment in the country was able to supply projectiles of suitable quality for use in them, and in consequence a quantity were procured from abroad. It became necessary, of course, that there should be a reliable source of supply in this country, and the bureau of ordnance offered encouragement for private manufacturers to embark in the business. The first concern that took up the subject seriously and successfully was the Carpenter Steel Co., of Reading, Pa., which on May 5, 1890, entered into contract to supply armor-piercing projectiles of various calibers. This company was followed by the Midvale Steel Co., of Philadelphia, in January, 1892, and by the Sterling Steel Co., of Pittsburg, Pa., in January, 1892, and others later on; and it soon became evident that not only could an abundant supply of armor-piercing projectiles be obtained in this country, but that the quality was fully equal, if not superior, to that of those manufactured abroad.

The most notable improvement in connection with armor-piercing projectiles was the introduction of the Johnson cap on June 21, 1897, that being the date on which the assignment of the patent was made to the government. The Johnson cap is a piece of soft steel securely attached to the point of the projectile, and its use increases the efficiency of the projectile when fired against hard-faced armor from 15 to 20%.

It had been known for some time that if a piece of soft metal was placed in front of and against a face-hardened plate, it would materially aid the projectile in its passage through the plate, and Mr. I. G. Johnson, of Spuyten Duyvil, N. Y., taking advantage of this fact, devised a scheme for firmly attaching a soft cap on the point of the projectile, which accomplished the same results. The advantages due to the use of the soft steel cap were fully demonstrated before the right to use it was acquired, and a great number of subsequent tests have confirmed the wisdom of the step, which was taken by the late Rear-Admiral Sampson, when chief of the bureau of ordnance.

For a number of years the contracts for armor-piercing projectiles required that when tested the test shells should pass unbroken through a caliber of hard-faced armor; that is, a 10-in. shell should pass unbroken through 10 ins. of hard-faced armor, and what were termed "common" shell; that is, steel shell having a capacity for a large bursting charge should pass through half a caliber of hard-faced armor; that is, a 10-in. common shell should pass unbroken through 5 ins. of armor, suitable velocities of impact being determined upon for each class.

Recently great improvements have been made in projectiles, and shell have been developed embodying the best features of both the armor-piercing and the common; that is, having the ability to carry a large bursting charge through the plate, and the requirements for these shell are that at a prescribed velocity they shall perforate a caliber of hard-faced armor and then be in a condition for effective bursting.

These projectiles were developed by the Firth-Sterling Steel Co., of Pittsburg, Pa., and it is believed that they are superior to any projectiles yet made in this country or elsewhere.

The manufacture of armor-piercing projectiles of first-class quality is by no means an easy undertaking, and great credit is due to the American manufacturers for their efforts in this direction; but it may be said that it would have been impracticable for them to develop them without the co-operation of the bureau of ordnance in furnishing armor plates and guns for the purpose of testing experimental shell. This was necessary, as no private manufacturer could afford such an outlay, and the use of a regular proving ground was also necessary.

We have seen, therefore, how modern guns, smokeless powder, and armor-piercing projectiles were introduced into the United States Navy, and it remains but to show the steps taken to introduce that other important element namely, armor.

ARMOR.

EARLY HISTORY.—While in all probability the question of protecting the hulls and crews of vessels of war from the missiles of an enemy had been a subject of serious consideration from very remote periods, the use of heavy plates of metal for such purpose is not of very remote origin.

In 1841, General Paixhan, a French officer, who a few years before had revolutionized naval artillery by the introduction of explosive shells in place of the solid shot previously used, recommended the application of iron plates to the sides of vessels for protection against the havoc of his own missiles, and although his plans were rejected by his own government, attention was drawn to the subject of armor for naval vessels.

As far back as 1812, John Stevens, of Hoboken, N. J., designed a vessel whose battery was protected by inclined armor. This early plan received no serious consideration by any government, but the Stevens family persevered in their investigations, and in 1842 Robert L. Stevens, a member of the same family, submitted to a Committee of Congress on Coast Defenses a report in which he published certain deductions concerning the laws of penetration of projectiles into iron armor, drawn from a long series of experiments. He also submitted a design of an iron-clad vessel, but the matter proceeded no further until the spring of 1854, when appropriation was made to build the ship, this action being taken a few months earlier than the commencement of the first iron-clad in Europe. The Stevens' battery was never completed, however; it remained in the same state in which it was left at the death of Robert L. Stevens in 1856 until after the death of Edwin A. Stevens in 1868. The latter bequeathed it to the State of New Jersey, together with the sum of $1,000,000 for its completion. This money was spent in 1869 and 1870, but the vessel was not launched, and in 1881 was broken up and sold as old material.

About two months after the laying of the keel of the Stevens' Battery, the French government began the construction of the iron-clad floating batteries "Devastation," "Lave," "Tounante," and "Congreve," at Toulon, and a few months later the English commenced the construction of the iron-clad vessels "Erebus," "Terrible," and "Thunderer."

On Oct. 17, 1855, the French batteries above referred to, with the exception of the "Congreve," forming the first iron-clad squadron ever seen, engaged the Kinburn forts in the Crimea, which had held at bay the combined fleets of France and England, silencing them in four hours.

These floating batteries were of about 1,600 tons displacement, and had a speed of scant four knots. Their armor consisted of 4½-in. solid plates backed by 27 ins. of oak, and their batteries were composed of 16 guns corresponding to 68-pdrs. They took positions of from 870 to 1,100 yds. off the main fort, which was armed with guns corresponding to 32-pdrs. The "Devastation" was hit 64 times and the "Tounante" 65 times, but their armor was but little injured, the penetration being only about 1½ ins.

Many are of the opinion that the engagements at Hampton Roads in March, 1862, between the Confederate iron-clad "Merrimac" and the U. S. frigates "Congress" and "Cumberland," and with the "Monitor," were the prime cause which led to the adoption of armored ships, but such is not the case; though it may, and no doubt did, have an important effect upon subsequent naval construction. It was the introduction of guns of greater energy, having longer range and greater accuracy than the smooth-bore guns, that rendered the use of armor a necessity, and prior to the conflicts in Hampton Roads, both England and France had each constructed a squadron of iron-clad floating batteries.

In 1858 the first squadron of sea-going iron-clad frigates, the "Gloire," "Normandie," "Invincible," and "Couronne," was commenced in France, and they were quickly followed in England by the "Warrior," "Black Prince," "Defense," and "Resistance."

The first sea-going ironclad that appeared was the "Gloire," in 1859, armed with rifled guns, and her performance on the ocean left no further doubt as to the sea-going qualities of which such vessels were capable, and from that time it was undeniable that armored ships must form at least a part of all navies. That this fact was generally accepted by all the principal maritime nations of the world except the United States, is evidenced by the fact that before the United States Congress had considered the question of ironclads, England, France, Spain, Italy, Austria, Denmark and the Southern Confederacy either had ironclads afloat or on the stocks, and before Ericsson had submitted the design of the "Monitor" to the Naval Commission, Captain Cowper Coles had demonstrated the advantages of the turret, mounted on low freeboard iron-clad hulls, in public, to the naval experts of England.

Before the United States had closed the contract with Ericsson for the "Monitor," the Danes had made one with Coles for the double-turreted sea-going ironclad "Rolf Krake," and her keel was laid before the "Monitor" was authorized.

In 1859 the French built an iron-clad vessel in 37 days from the laying of the keel.

At the extra session of Congress, which convened on July 4, 1861, pursuant to the proclamation of President Lincoln, a report was submitted by Gideon Wells, Secretary of the Navy, in which he adverted to the fact that other governments were constructing armored vessels, and he recommended that initiatory measures should be taken by our government for the construction of "one or more iron-clad steamers or floating batteries." Congress responded promptly and liberally to this recommendation, and on Aug. 3, 1861, passed an act authorizing and directing the Secretary of the Navy to appoint a board of three skilful naval officers to investigate the plans and specifications that might be submitted for the construction or completion of iron or steel-clad steamships or steam batteries, appropriating the sum of $1,500,000 for the construction of one or more of the same should the plan be approved. On August 7, or four days after the passage of the act above referred to, the Navy Department issued an advertisement "for the construction of one or more iron-clad steam vessels of war, either of iron or of wood and iron combined, for sea or river service; to be of not less than 10 nor more than 16 ft. draft of water; to carry an armament of from 80 to 120 tons weight, with provisions and stores for from 165 to 300 persons, according to armament, for 60 days, with coal for eight days. . . . The vessels to be rigged with two masts, with wire-rope standing rigging, to navigate at sea. Propositions to be received for 25 days."

On the following day (Aug. 8, 1861,) the Secretary of the Navy appointed a board composed of Commodore Joseph Smith, U. S. N.; Commodore Hiram Paulding, U. S. N., and Captain Charles H. Davis, U. S. N., to consider such plans as might be received.

In Sept. 18, 1861, Mr. C. S. Bushnell, of New Haven, brought to notice of Secretary Wells, Captain John Ericsson's plans of the original "Monitor." Mr. Wells was favorably impressed with them that he suggested that Mr. Bushnell should proceed to Washington and exhibit them to the board, upon which suggestion Mr. Bushnell at once acted.

On Sept. 16, 1861, the board submitted its report, which embraced the plans presented by 17 bidders. Three propositions were favorably considered, namely those of John Ericsson, of New York; C. S. Bushnell & Co., of New Haven, and Merrick & Sons, of Philadelphia. With regard to Ericsson's design the board remarks:

> This plan of a floating battery is novel, but seems to be based upon a plan that will render the battery shot and shell proof. We are somewhat apprehensive that her properties for sea are not such as a sea-going vessel should possess, but she may be moved from one place to another on the coast in smooth water. We recommend that an experiment be made with one battery of this description on the terms proposed, with a guarantee and forfeiture in case of failure in any of the properties and points of the vessel as proposed.

On Oct. 4, 1861, the Navy Department entered into contract with Captain Ericsson for a vessel on his plan, which was described as "an iron-clad, shot-proof steam battery of iron and wood combined." Her dimensions, etc., were length, 172 ft.; breadth, 41 ft.; depth of hold, 11½ ft.; draft of water, 10 ft.; displacement, 1,255 tons; speed, 9 statute miles per hour; time of completion, 100 days; contract price, $275,000. The "Monitor" was completed within the time specified, and sailed from New York to Hampton Roads on March 6, 1862, reaching the latter on March 8th, and on the following day had her memorable encounter with the Confederate iron-clad steamer "Merrimac."

This, then, was the first iron-clad vessel built for the United States Government, and, aside from the novelty of her design, did not represent by a long way the development which had taken place abroad in armored ships. Her decks, sides and turret were protected with iron plates—about 1 in. thick—built up in layers, and her armament consisted of two 11-in. cast-iron, smooth-bore guns.

When we contrast our first ironclad of 1,255 tons displacement and nine knots speed, built in 1861, with the sea-going battleship "Louisiana" of 16,000 tons displacement and 18 knots speed, carrying 3,947 tons of material for protection only, and an armament with its ammunition weighing 1,536 tons, it conveys some idea of the progress of development of ships of war.

It may be safely asserted that prior to 1854 the manufacture of armor plate had not become a distinct industry. Between the years 1854 and 1858 the manufacture of solid armor plates was limited to those of a thickness of 4½ ins., and it was not until 1859 that any marked advance became apparent.

The history of the development of armor shows the vast amount of time and money expended in the effort to produce novel types of superior resisting power that would effect a saving in weight and in cost. During these investigations target structures of almost every conceivable description were made and subjected to ballistic test. There were homogeneous cast-iron and wrought-iron plates, and built-up targets of every description, including sheets of metal bolted together and presented flat or edgewise; alternating layers of metal and wood; of metal and rubber disposed in various ways, and of springs behind solid plates and between the laminations of built-up plates. The targets were fired at vertically and inclined at various angles.

The result of all these experiments, most of which were made abroad, was the general adoption in the period just prior to the Civil War of homogeneous wrought iron for armor, the plates being secured vertically to the sides of the vessel and attached rigidly to wooden backing.

The outbreak of the Civil War not only found the United States Government without any armor-clad vessels, but with no facilities in the country for making anything but very thin plates, and it was therefore forced to make use of such material for the protection of vessels built at that period.

The U. S. Navy Register of 1864 contains among the list of vessels of the navy the names of 73 "ironclads," showing that the use of armored protection for vessels of war, even though of an inferior quality, was recognized

as an essential feature of their construction at that period.

The vessels above-referred to consisted of the double and single-turreted monitors, several of which remain on the navy list to-day, though the vessels themselves are of but little military value, having obsolete guns and very inferior armor; of the so-called light-draft monitors, which proved to be utter failures, and of which none happily remain, and of a number of Mississippi River steamers which had been adapted for military purposes, and a few of more notable type, namely, the "Dunderberg," "New Ironsides," "Galena," and "Keokuk."

The same publication contains a list of United States ironclads which had disappeared from service during the Civil War, namely, the "Cairo," sunk by a torpedo in Yazoo River on Dec. 12, 1862; the original "Monitor," foundered off Cape Hatteras, Dec. 31, 1862; the "Indianola," captured in the Mississippi River, Feb. 24, 1863; the "Cincinnati," sunk by the batteries at Vicksburg, May 27, 1863, and raised in the following August; the "Baron de Kalb," sunk by a torpedo in the Yazoo River, July, 1863; the "Keokuk," sunk by gun fire off Charleston, S. C., April 7, 1863; the "Weehauken," sunk off Charleston, S. C., Dec. 6, 1863, and afterwards raised; the "Eastport," destroyed in Red River to escape capture, April 26, 1864; the "Tecumseh," sunk by a torpedo in Mobile Bay, Aug. 5, 1864, and the "Patapsco," sunk by a torpedo in Charleston Harbor, Jan. 15, 1865.

The armor of nearly all of the United States vessels of this period consisted of several layers of thin plates, each about 1-in. thick, laid on heavy wooden backing, and while of very inferior quality as viewed from the present standpoint of efficiency, it proved to be quite effective against the artillery then opposed to it.

The old monitors received many hits off Charleston, some of the records being as follows: "Montauk," hit 214 times; "Weehauken," 187 times; "Patapsco," 144 times; "Passaic," 134 times; "Catskill," 106 times; "Nahant," 105 times; "Nantucket," 104 times; "Lehigh," 36 times, and the "New Ironsides," 193 times. Many of these hits were from 10-in. Columbiads, and though the vessels as a rule were able to remain at their stations, they suffered considerable injury, though but little was said about it at the time.

THE "DUNDERBERG."—The most notable United States ironclads of that period were the 'Dunderberg" and the "New Ironsides," and a few words concerning them may not be without interest.

The "Dunderberg" (or Thundering Mountain) was built by Wm. H. Webb, of New York, at New York, and is described in the official papers as "an ironclad, shot-proof, steam screw ship of war with ram, to be built of wood and cased with iron." It was designed to carry two revolving gun-turrets on the casemate deck, each to be not less than 21 ft. in diameter and 8 ft. high in the clear, the armor iron of which not to be less than 11 ins. thick; each turret to contain two guns of 15-in. caliber, and in the casemate eight 11-in. Dahlgren guns were to be carried. There was to be a "shot-proof pilot house" on one of the turrets or on the casemate deck. The engines and boilers were to be "of sufficient capacity to propel the vessel at least 15 knots per hour for 12 consecutive hours in fair weather and smooth water at sea;" the engines to be of the low-pressure condensing type; the turrets to be turned by steam; the vessel to be completed in 15 months from July 3, 1862; the guns to be supplied by the government, but the contractors to furnish the gun carriages; contract price $1,250,000 in 25 payments of $50,000 each; the port shutters to be of wrought iron 4½ ins. thick; the outer hull to be of wood 6 ft. thick at the main deck level, decreasing to 2 ins. at the bilge; the underwater body to be coppered; the sides of the vessel from the main deck to about 5 ft. below the load-water line to be covered with iron 3½ ins. thick from deck to water line and then tapering to 2½ ins. at the lower edge, and also tapering towards the bow and stern to 2½ ins., made in slabs placed vertically. The sloping sides and ends of the casemate were to be covered with iron plates 4½ ins. thick, made in one thickness, and not less than 28 ins. wide, or wider if they could be manufactured.

Extreme length	380 ft. 4 ins.
Extreme breadth	72 " 10 "
Depth of main hold	22 " 7 "
Height of casemate	7 " 9 "
Length of ram	50 "
Draft, ready for sea	21 "
Displacement	7,000 tons.
Tonnage	5,090 "
Weight of iron armor	1,000 "
Diameter of steam cylinders (2)	100 ins.
Stroke of piston	45 ins.
Boilers	6 main and 2 auxiliary.
Height of boilers	17 ft. 6 ins.
Front width of boilers	21 ft. 5 ins.
Weight of boilers	450 tons.
Total heating surface	30,000 sq. ft.
Total grate surface	1,200 " "
Cooling surface in condensers	12,000 " "
Diameter of screw propeller	21 ft.
Pitch of screw propeller	27 to 30 ft.
Weight of screw propeller	34,580 lbs.
Capacity of coal bunkers	1,000 tons.
Indicated horse-power	5,000

Smokestack, 13 ft. diameter with armored gratings.
Engines to be horizontal back-acting, designed to run at 60 revs. per min. at ordinary and at 80 at full speed.
Main shaft 118 ft. long by 18 ins. diameter.

The accompanying table exhibits the general dimensions of the ship and her machinery, and shows her to have been an unusually huge craft for her day.

The armament as projected was probably more than the ship could carry, and it was finally decided to omit the turrets and the turret guns, and to give the vessel two 15 and four 11-ir. guns; one 15 and one 11-in. to be mounted on each broadside and one 11-in. at each end of the casemate. This battery was mounted about February, 1867, from which it will appear that instead of being completed in October, 1863, as required by the contract, the vessel was not completed until 3½ years later.

On the 22d of February, 1867, the "Dunderberg" went to sea to test her battery, and its general performance was reported as satisfactory. On account of the omission of the turrets a deduction of $22,860 was made from the contract price. It does not appear that a regular speed trial was made, but it is recorded that at one time a speed of 10 knots was attained with 41 revolutions of the screw, with a boiler pressure of 17 lbs. per sq. in.

After the vessel was completed she was by authority of Congress turned over to the builders upon payment by them of all moneys paid or advanced by the government, and under the terms of the act of March 2, 1867, Mr. Webb had to pay back to the United States Treasury the sum of $1,041,666.68 which had been paid him on account, and on June 27, 1867, he paid into the Treasury in cash, checks, etc., the sum of $1,092,887.73, the difference being for articles of equipment and for two 15-in. guns, ammunition, etc., purchased by him for the ship from the government.

The ship was then sold by him to the French government, and after some alterations was put in the service of the French navy under the name of "Rochambeau." There are no records available showing the nature of these alterations or her later history.

THE "NEW IRONSIDES."—The "New Ironsides" was designed and built by the Cramp Shipbuilding Co., of Philadelphia, but the scheme of the vessel was due to Mr. H. B. Bartol, of the Philadelphia engine-building firm of Merrick & Co. She was called a casemated iron-clad frigate, with unarmored ends, except that her water line was protected by a complete belt. Her battery consisited of 14 11-in. smooth-bores and two 8-in. Parrott rifles, mounted in a casemate. Her speed was about 6 knots, as she was supplied with the machinery that had been built for a corvette of the "Wyoming" class; she had, however, a good speed of sail in addition. Her armor consisted of 4½-in. solid iron plates, backed by 21 ins. of oak, the inclination of the casemate being 30° from the perpendicular. The armor plates were manufactured at Pittsburg.

For two years this ship was subjected to the most severe test a war vessel can undergo—alternate blockade duty and close action against fortifications. On one occasion she remained in action three hours alone against the combined forts of Charleston Harbor, holding down the artillery fire of the batteries until she was obliged to haul out for lack of ammunition. During this time she was struck on her side armor 60 times, but an investigation showed her to be entirely uninjured. In a period of about six months the "New Ironsides" was struck 193 times, and was never forced to leave the station for repairs. After the Civil War this vessel was laid up at League Island, Philadelphia, and was destroyed by an accidental fire.

The Confederate iron-clad steamers "Merrimac," "Atlanta," and "Tennessee" are well worthy of mention, as when we consider the limited means at hand and the lack of skilled labor available, the results achieved cannot but excite the admiration of naval people.

CONFEDERATE IRONCLADS.—As is well known the "Merrimac," or "Virginia," as she was officially known, was the United States frigate "Merrimac," which fell into the hands of the Confederacy at the Norfolk Navy Yard when it was abandoned by the United States forces. She was cut down and a heavy casemate of timber was built upon her, which was covered with two layers of narrow bars of rolled iron, each 1½ ins. thick, making a total of 3 ins. These slabs were rolled from railroad iron and were therefore of excellent material. This iron plating was laid over 20 ins. of oak, and was placed at an angle of about 30° from the horizontal. So far as known no material damage was done to the armor of the "Merrimac" by the fire of the "Cumberland," "Congress," or "Monitor."

The Confederate steamer "Atlanta" was built by converting an iron-hulled blockade-running steamer called the "Fingal." Additional displacement was given her by sponsoning her out with square logs, thus increasing her beam, and she was fitted with a central casemate or citadel built of 15 ins. of Georgia pine covered by 3 ins. of oak, on which were laid two courses of 2-in. iron bars, 7 ins. wide (probably rolled from railroad iron), the inner layer being horizontal and the outer one vertical, the fastenings being 1¼-in. through bolts set up with nuts and washers. She had a battery of two 6-in. and two 7-in. rifles. The sides of the casemate were inclined at an angle of about 30° from the horizontal.

The "Atlanta," under the command of Capt. Wm. A. Webb, of the Confederate navy, was captured by the U. S. Monitor "Weehauken," Capt. John Rodgers, on July 17, 1863, in the sounds of North Carolina. The "Weehauken" fired five shots, three of which took effect, penetrating the "Atlanta's" armor, and killing or wounding many of the crew of two guns; she was struck by two 15-in. and one 11-in. shot, and grounded and surrendered.

The "Tennessee" was after the same type as the "Atlanta," but was built of wood and specially constructed for use as a vessel of war, and was therefore somewhat heavier. The framing of the casemate consisted of an inside diagonal ceiling of 2½-in. oak, vertical pine timbers 13 ins. thick, yellow pine planking 5½ ins. thick, an outside layer of 4 ins. of oak timber covered by three thicknesses of 2-in. iron bars, 7 ins. wide; the whole fastened by 1½-in. through bolts set up with nuts on the inside. The armor of the ends of the casemate was 1 in. less in thickness. At the battle of Mobile Bay a 15-in. shot from one of the monitors smashed in the port side of the "Tennessee's" casemate, though the shot itself did not get through. She was struck many times and suffered much injury.

PLAIN, COMPOUND AND NICKEL-STEEL ARMOR.—From the vessels above described to the steel-clad floating fortresses of to-day was a gigantic stride, though the time required for its accomplishment was by no means great.

The first of the armored vessels of the modern navy were the "Maine" and "Texas," authorized by the act of March 3, 1886, which act also provided for the reconstruction of the monitors "Puritan," "Monadnock," "Amphitrite" and "Terror."

The above authorization was followed by the issue of a circular by the Navy Department, dated Aug. 21, 1886, inviting bids for armor-plate and gun-steel of domestic manufacture; and the consideration of the manufacture of modern armor in the United States may be said to date from the issue of this circular. The bids received under this advertisement were opened on March 22, 1887, proposals being received from the Bethlehem Iron Co., of South Bethlehem, Pa., for both; from the Cambria Iron Co., of Johnstown, Pa., and from the Midvale Steel Co., of Philadelphia, for gun-steel only, and from the Cambria Rolling Mill Co., of Johnstown, Pa., for armor plates only. The bid of the Bethlehem Iron Co. being the only one for both kinds of material, and being in the aggregate the lowest, was accepted, and a contract was made with that company on June 1, 1887, for both armor and gun steel. This contract included armor for the second-class battleships "Maine" and "Texas," and for monitors "Puritan," "Monadnock," "Amphitrite," and "Terror."

The amount of armor contracted for was estimated at about 6,700 tons, and was to be of plain steel, oil-tempered and annealed, but prior to the first deliveries, which were made in the fall of 1891, radical changes were made in the specifications, and the introduction of nickel and the use of the reforging and face-hardening processes were included.

About the year 1888, a sufficient quantity of armor was ordered from England for the monitor "Miantonomoh"; this armor being of the type known as "compound armor," its cost being $535 per ton.

Prior to the date of the circular above referred to numerous experiments had been made in England, Russia, Italy, France and Germany of various types of armor, and from 1882 to 1887 the contest for superiority lay between the compound and the all-steel plates, English manufacturers presenting the former, while Messrs. Schneider, of France, were the chief advocates of the latter.

Compound armor generally resisted penetration better than the all-steel plate, because it was possible to make the thin steel face of the former much harder than that of the all-steel plate, without sacrificing the toughness necessary to prevent breaking up.

The chief failure of the compound plate was in the flaking off of the steel face from its iron back. This led to a continued effort to produce all-steel plates that would present a hard face and still retain sufficient toughness. By the introduction, in 1889, of a small percentage of nickel in the manufacture of steel, unusual toughness was produced.

Such was the armor situation when the United States government commenced the building of armored vessels for its new navy, and while, as previously stated, the armor ordered for the first of the new vessels was of plain seel, it gave place to that containing nickel, as the result of the first important armor test made in the United States at the Annapolis proving ground in September, 1890; this test being made principally to determine the respective value of plain steel, of nickel steel, and of compound armor plates.

To carry out this experiment three plates of equal dimensions were procured, namely, 8 ft. × 6 ft. × 10½ ins., and were subjected to similar attacks. The plates tested consisted of a compound plate made by Cammel & Co., of England, a plain steel plate made by Schneider & Co., of France, and a nickel-steel plate also made by the latter. All three plates were subjected to five impacts, four by a 100-lb. armor-piercing projectile fired from a 6-in. gun, with a striking velocity of 2,075 ft.-secs., one shot being directed at each corner of the plates, and a fifth impact by a 210-lb. projectile, fired from an 8-in. gun, with a striking velocity of 1,850 ft.-secs., at the center of the plates. All three plates were supported by 36 ins. of oak backing.

The compound plate was perforated by all the shell, and was practically destroyed by the 6-in. alone. The plain-steel plate kept out al the shell, but was badly cracked by the 8-in. The nickel- steel plate kept out all the shell, and remained without cracks. After these tests it was decided to use nickel-steel for the armor of United States vessels, and the Navy Department took immediate steps to procure a large supply of nickel-matter for such purpose.

HARVEYED ARMOR.—Probably no step in the development of modern armor is more interesting or was of greater importance than was the introduction of the Harvey process of face-hardening, originated by Mr. Hayward Augustus Harvey, who was born at Jamestown, New York, Jan. 17, 1824. At the time he conceived the idea of face-hardening steel plates (1889) he was President of the Harvey Steel Co., of Newark, N. J. During that year he treated a block of steel with a view to giving it a very hard face and great power of resistance, and was so successful that he brought his experiments to the attention of the Navy Department, which at his request furnished him a small plate 6 ins. in thickness, which was treated at the company's works in Newark; was face-hardened at the Washington Navy Yard under Mr. Harvey's directions, and was tested at the Naval Proving Ground at Annapolis in 1890.

This plate was made by the Linden Steel Co., of Pittsburg, and was cut in halves, and one-half was treated by the Harvey process and the other half left untreated. When tested the treated part showed such superior qualities of resistance over the untreated half that the Navy Department decided to experiment on a larger scale, and therefore procured from Messrs. Schneider & Co., of Le Creuzot, France, a steel plate 10½ ins. in thickness for the purpose, there being at that time no facilities in this country for the manufacture of such plates.

This plate was treated at the Washington Navy Yard in January, 1891, in a furnace especially erected for the purpose, under the direction of Mr. Harvey, in which the process of super-carburization was performed. The bed of the furnace being first covered with sand a few inches thick, the plate was laid thereon in a horizontal position, and its upper face, which was to be treated, was covered with a layer of carburizing material, probably a mixture of animal and vegetable charcoal, about a foot thick, over which was laid a covering of tiles to exclude the flame and air from the plate. The doors of the furnace were bricked up and the fires were started, and it was brought up to a high degree of heat, which was maintained for about 100 hrs.

Much difficulty was experienced in getting the heated plate out of the furnace, and a period of 5 hrs. was consumed for this purpose, as the arrangements were very crude. When the plate was finally free from the furnace and was hauled under the sprinkling trough, it was of a dull cherry red color, and in this condition was heavily sprayed on one side with jets of cold water, which fell several feet from the trough above. The cooled surface naturally contracted and distorted the plate, which curled up like a saucer under the influence of the chill. The spraying was continued until the plate was cooled to black heat, when it recovered its shape somewhat, but the warping was then regarded as a serious objection to the process, but in future plates this was overcome by spraying the heated plates on both sides; and in the regular furnaces thereafter constructed the plates were laid on iron cars and could then be readily removed.

The writer of this article was then in charge of the Naval Gun Factory, and thus had charge of this interesting experiment, which was to cause so great a revolution in the character of the armored protection of ships of war of all nations.

This imperfectly treated plate was tested at the Indian Head Proving Ground in February, 1891, being attacked by seven 6-in. projectiles of 100 lbs. weight, having a striking velocity of 2,065 ft.-secs.

The greatest penetration was 4 ins., except in one round, that at the center of the plate, when the point of the shell reached the backing. All the projectiles were broken up. The plate was cracked, but until the last round no part of it was detached from the backing. At this round about one-eighth of the plate fell to the ground. These results were considered remarkable, and it was concluded that by means of this method of treatment armor of ideal quality—that is, having a very hard face combined with a tough back, without any weld or other line of demarcation between them, could be made.

The Navy Department, therefore, decided to hold a further series of armor trials in which the relative merits of plain and nickel steel of domestic manufacture, when treated by the Harvey process, should be submitted to exhaustive competition. Accordingly, eight plates, each 6 ft. by 8 ft. by 10½ ins., were ordered; five from Carnegie, Phipps & Co. and three from the Bethlehem Iron Co.

The tests of these plates took place at Indian Head, Maryland, on Oct. 31, and Nov. 14, 1891, but only six plates wer fired at, as two of those furnished by Carnegie, Phipps & Co. were withdrawn on account of defects in manufacture.

Each plate received four impacts from 6-in. shell, one at each corner, and one 8-in. shell in the center. The 6-in. shell weighed 100 lbs. and were fired to give a striking velocity of 2,075 ft.-secs. The 8-in. shell weighed 210 and 250 lbs., respectively, and were fired to give striking velocities of 1,850 and 1,700 ft.-secs., the energy being the same in either case.

The three Bethlehem plates used were, respectively, a high-carbon nickel-steel, a medium-carbon nickel-steel Harveyed, and a plain steel Harveyed. The three Carnegie, Phipps & Co. plates were, respectively, a high-carbon nickel-steel, a low-carbon nickel-steel, and a low-carbon nickel-steel Harveyed.

All the plates showed greater resistance to penetration and less cracking than did the English compound plate of the previous year. Two of the plates showed greater resistance to perforation and less cracking than did the most resisting plate at the Annapolis test of the previous year.

The results given by the nickel-steel plate tested by the Harvey process, manufactured by the Bethlehem Iron Co., were considered the most satisfactory; and the conclusion was reached that two important results had been achieved: First, a better plate of American manufacture had been produced than the Department was able to purchase abroad the year previous; secondly, the development of a new principle in the manufacture of armor of American origin, which there were good grounds for believing would furnish greater protection to the vital parts of a vessel of war than any other system hitherto employed.

While the foregoing tests were considered very conclusive, the Navy Department decided to make still another before finally adopting the Harvey process, and in the latter part of 1891 two more 10½-in. nickel-steel plates were ordered from the Bethlehem Iron Co., both of which were treated by the Harvey process and tempered by an improved method. These two plates differed in one respect, namely, the first having been forged to 12½ ins., and, after supercarburization, being further reduced by forging to 10½ ins.; the second being forged to final dimensions—that is, to 10½ ins. before Harveyizing. The chemical and physical properties of the plates before treatment were the same.

These plates were tested at Indian Head on July 23 1892, under precisely the same conditions as those of October and November, 1891, and established not only the value of the Harvey process, but also that of reforging after supercarburization; and it was determined that thereafter all armor for the Navy should be so treated.

Improvements in manufacture followed from time to time, and the so-called Harveyed plates held the lead in all countries until a modification thereof was made at the works of Herr Krupp, in Germany, 1895.

KRUPP ARMOR.—The first important mention of the new Krupp process dates from the test of an 11.8-in. plate at the company's proving ground at Meppen on Sept. 15, 1895. From published statements the plate above referred to showed unusually good ballastic qualities and such immunity from cracking that it was referred to as the champion thick experimental plate.

The principal English manufacturers acquired the process, and in 1897 Messrs. Vickers, Sons & Co. presented for official test an 11 11-16-in. and a 6-in. plate, both of which gave excellent results and fully bore out the reputation which the new Krupp process had attained in Germany. Other British manufacturers presented plates made by the new process, and the superiority of such armor was so fully established that its adoption became an assured fact, it being merely a question of the ability of the manufacturers to produce it, as its manufacture necessitated extensive alterations to the then existing armor plants.

The American armor manufacturers, having acquired the rights to use the new process, submitted in July, 1898, the first Krupp plate manufactured in this country, the credit for so doing belonging to the Carnegie Steel Co., and in October of the same year the Bethlehem Steel Co. also submitted an experimental plate, both companies following with second plates.

The tests of these plates showed their excellence, and also that the American manufacturers could produce armor by the new process equal to that made abroad.

The Krupp process is in fact an improvement on the Harvey process, and the alloy used is referred to as nickel-chrome, as both of these metals enter into its composition; and the process of supercarburization in the case of the Krupp plates is produced by means of a hydro-carbon gas instead of by means of a solid carbonizing material, as was the case with the Harvey process.

Krupp plates are not only tougher and more resisting than Harveyed plates, but they have the peculiarity of not cracking under heavy impacts, which is a matter of great moment. The superiority of armor plates manufactured by the Krupp process is more apparent in the case of thick plates than in thin ones, and it is an open question whether in plates of not over 5 ins. in thickness the Harveyed plates are not equally as good.

The armored ships now building and those about to be commenced will all carry Krupp armor for all plates over 5 ins. in thickness, and possibly for some of the thinner plates.

For a number of years the cost of armor plate was under discussion by both houses of Congress, and various restrictions were imposed, which led to many complications and delays in the completion of vessels under contract; but the Act of June 7, 1900, provided:

That the Secretary of the Navy is hereby authorized to procure by contract armor of the best quality for any or all vessels above referred to, provided such contracts can be made at a price which in his judgment is reasonable and equitable; but in case he is unable to make contracts for armor under the above conditions, he is hereby authorized and directed to procure a site for and to erect thereon a factory for the manufacture of armor, and the sum of four million dollars is hereby appropriated towards the erection of said factory.

Under the above provisions the Secretary of the Navy, after public advertisement and prolonged negotiations, made contracts for 37,184 tons of armor, more or less, covering all the armor required for vessels authorized for which no provision had been previously made. The amount of armor previously ordered amounted to 35,773 tons, so that the total quantity of armor ordered for the ships of the new navy since July 1, 1887, amounts to 72,957 tons.

WROUGHT-IRON ARMATURE FRAMES FOR LARGE ALTERNATORS.

A rather interesting novelty in alternator construction has recently been put into practice by the Siemens & Halske Co., of Berlin, Germany—the use of riveted wrought-iron armature frames. Cast iron has been used hitherto as a material for the frames, but as alternators grew larger these narrow large ring castings gave much trouble in machining and erecting. They were heavy, and due to their shape were quite deficient in stiffness, in spite of their cored box construction, difficulties which increased with the size of the alternators. As these frames are in general purely structural elements, supporting the laminated core ring on which the armature coils are wound, the use of wrought iron or steel suggested itself as a means of reducing the weight and increasing the strength and stiffness of the frames.

The accompanying drawings, Figs. 1 and 2, show two examples of wrought-iron frames. That represented in Fig. 1 is for a very large alternator, the bore of the armature being 19 ft. 8 ins., and the width of the core about 9 ins. To the left

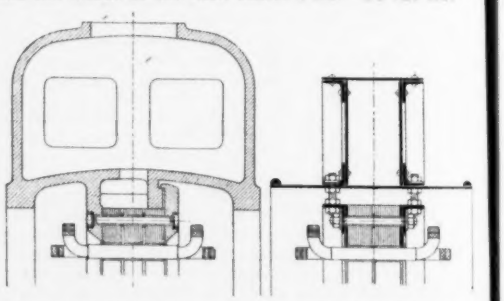


Fig. 1. Armature Frame for Large Alternator in Cast Iron and in Wrought Iron.

is shown in section a cast-iron frame for this size of machine, while to the right is the corresponding wrought-iron frame. The difference in the amounts of metal required for the two constructions is apparent. As will be seen the wrought-iron frame is in effect an annular box girder, following closely the box-shaped section of the cast-iron frame. The frame is riveted up of plates and angles in the same manner as regular structural steel work. The method of supporting the laminated core ring should be noted. The core punchings are firmly bolted between two rings of angle and plate and the whole core ring is then hung in the main frame by bolts with double nuts, so that it can be accurately centered and adjusted. The section of frame shown in Fig. 2 is designed for a much smaller machine. The load to be carried is here so small that the box construction is not required, sufficient stiffness being given by bent channel iron riveted to the outside of the main ring plate. The support of the core ring is similar to that used in case of the wrought-iron frame in Fig. 1. For our illustrations we are indebted to the "Zeitschrift des Vereins Deutscher Ingenieure."

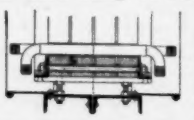


Fig. 2. Wrought-Iron Armature Frame Construction for Small Alternator.

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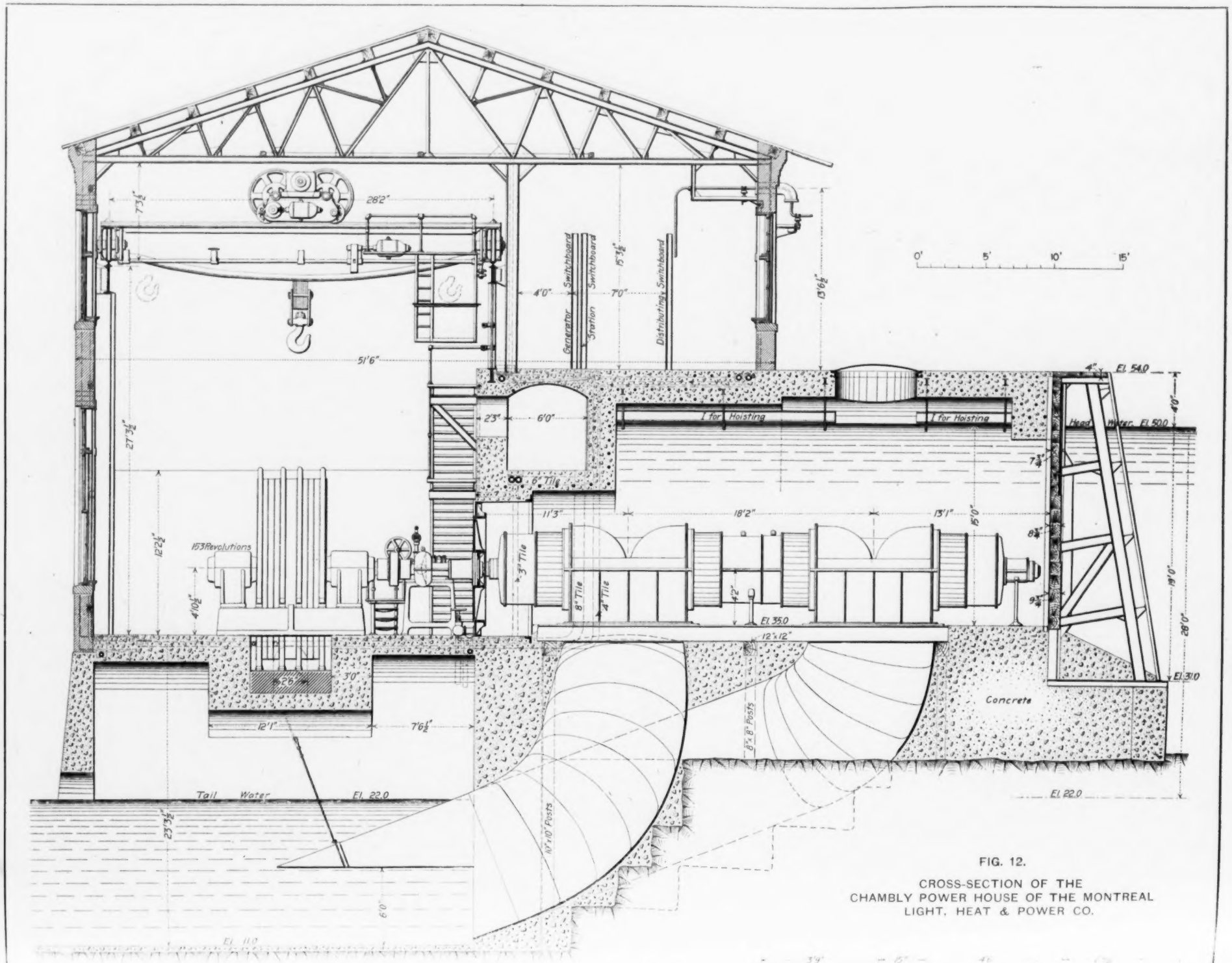
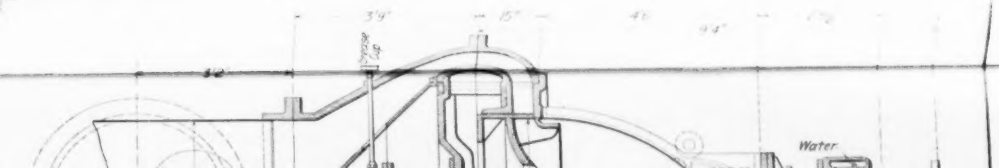


FIG. 12.

CROSS-SECTION OF THE CHAMBLY POWER HOUSE OF THE MONTREAL LIGHT, HEAT & POWER CO.

TURBINES IN RECENT AMERICAN WATER POWER PLANTS.



TURBINES IN RECENT AMERICAN WATER POWER PLANTS.

(Accompanying Paper by John Wolf Thurso on "Modern Turbine Practice.")

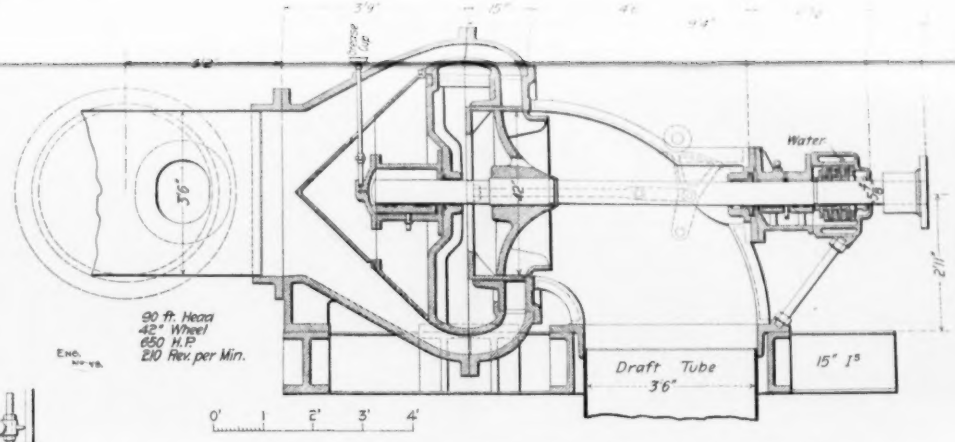


FIG. 22. 650-HP. TURBINE FOR MESSRS. J. & J. ROGERS, AUSABLE FORKS, N. Y.
BUILT BY STILWELL-BIERCE & SMITH-VAILE CO., DAYTON, O.

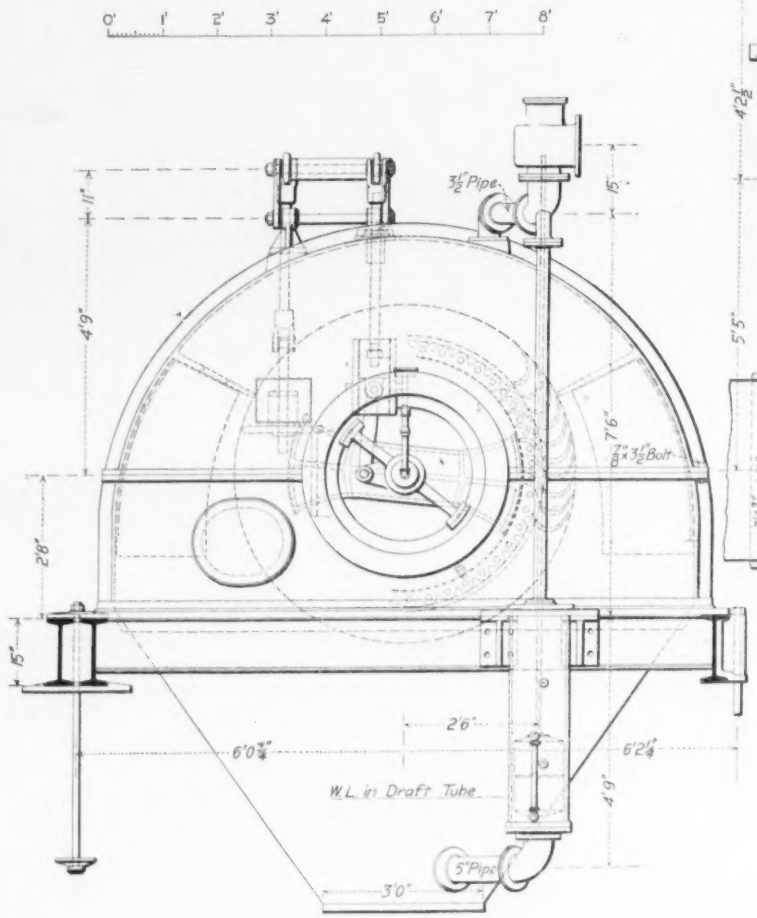


Fig. 23.

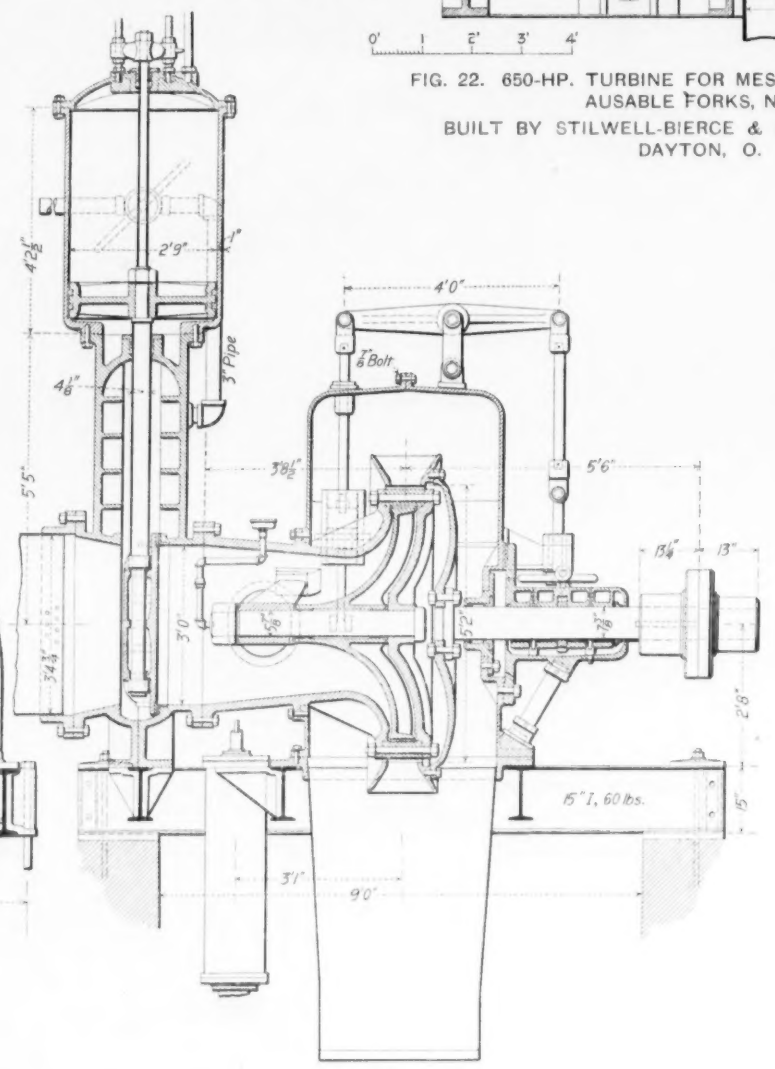


Fig. 24.

FIGS. 23 AND 24. 1,000-HP. TURBINE FOR THE OUIATCHOUAN PULP CO., OUIATCHOUAN, QUE.
BUILT BY STILWELL-BIERCE & SMITH-VAILE CO., DAYTON, O.